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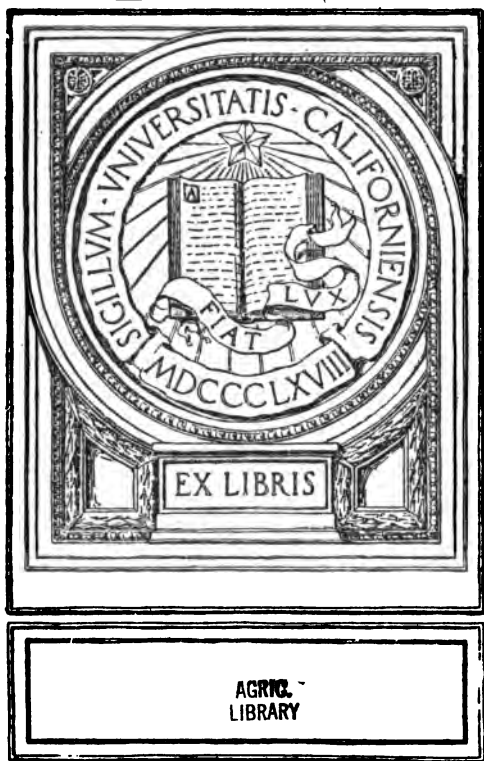
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LESPEDeza
(Japan Clover)

BY

S. H. ESSARY



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Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

LESPEDEZA (Japan Clover)

By
S. H. ESSARY

SUMMARY

1. Lespedeza (*Lespedeza striata*), or Japan clover, was introduced into the Southern States from eastern Asia some time before the Civil War. Its present range is from New Jersey west to Kansas and south to the Gulf. It reaches its greatest importance in the southern part of the Mississippi Valley. Over the rest of its range it is valuable chiefly for pasture and soil improvement. It grows in all parts of Tennessee, but ranks in importance with other legumes only in the western part of the State.

2. Lespedeza ranks well with alfalfa and the clovers as a valuable forage plant, and is superior to them in many situations, especially as a renovator of worn lands.

3. Lespedeza is an annual, coming from seed each year, but under practically all conditions where it grows it reseeds itself. Common varieties have a spreading habit when the plants are scattered, but in thick stands grow erect. Flowers are produced from the middle of summer till frost, and ripen an abundance of seed.

4. Lespedeza is often confused with hop clover, but is readily distinguished from hop clover by the time of development, color and form of flowers, and shape and arrangement of leaves.

5. Many native species of *Lespedeza* are found in Tennessee. They are all perennial, and none of them resemble Japan clover enough to be mistaken for it. They are of little agricultural value.

6. Lespedeza should be seeded early in the spring, on a well-prepared seed-bed, and covered lightly. It may be seeded in grain or grass crops, but should be sown in the spring following the seeding of the other crops. A bushel of seed to the acre should be sown when lespedeza alone is grown, but with other crops a smaller quantity is required.

7. When harvested for hay, lespedeza should be cut before the leaves drop or the stems become hard. When harvested for seed, the cutting should be deferred till the end of the growing season, usually about the time of frost. The hay in either case should be

handled carefully, as the leaves and seed shatter off easily. Curing is commonly done in shocks, and it is a good practice to cover the shocks with hay caps made of cotton sheeting.

8. Lespedeza seed may be threshed from the hay with a grain thresher or collected in a seed pan attached to the cutter bar of the mowing machine.

9. The seed of lespedeza germinate well when fresh. About 50 per cent of two-year-old seed germinate. Seed three years old or more should not be planted.

10. Lespedeza is inoculated wherever found growing in Tennessee, and no artificial inoculation is required. It gathers a considerable amount of nitrogen from the air.

11. The addition of lime to the soil has a beneficial effect upon the yield of lespedeza hay. This effect was found to last at least three years.

12. Lespedeza is a good pasture plant, whether grown alone or in combination with grasses. The best results are obtained when it is in combination with crops that make a good early spring growth.

13. Lespedeza compares very favorably with other legumes in yield of hay. The yield depends upon the season, the stand, and the fertility of the soil. Two tons to the acre is about an average yield on good soil, but four tons is not an unusual yield. The seed yields vary as much as the hay yields, and run from four or five to twenty bushels per acre.

14. Crabgrass is the most common weed in lespedeza fields, but other weeds are often present. It is necessary to mow the fields once or twice during the summer to remove the weeds, after which the lespedeza will control them. Dodder is frequently a source of serious trouble. There are few insect or parasitic enemies of lespedeza.

15. Common lespedeza is not a single variety, but a mixture of slightly differing varieties, which can be separated into early or late, small or large varieties.

16. The Tennessee Station has selected and propagated three new varieties, which seem to be superior to the mixture usually grown. One of these is well adapted for hay, one for pasture, and one for growing in sections of the State where the season is short. These varieties are described in this bulletin.

17. Lespedeza will not take the place of alfalfa and the clovers, but will supplement them, in that it will grow on any kind of soil and is easily and cheaply grown and handled. It also comes into a field naturally, which the others do not, and makes good pasture and hay, about equal in value to those of the other legumes mentioned.

INTRODUCTION

Lespedeza (*Lespedeza striata*), or Japan clover, is a native of eastern Asia. It is found growing wild in China, Manchuria, Mongolia, Korea, and Japan, but is not widely cultivated, if at all, in those countries. Just when or how it was introduced into America is a debated question. It was found and described in Georgia in 1846. The first specimen described is still preserved in the Gray Herbarium. Seed is supposed to have been brought to this country accidentally in packing material with shipments of goods from Japan. The popular belief is that it was introduced during the Civil War and widely scattered by the movement of armies over the South. The plant was common throughout the Southern States soon afterward, but for some years was not regarded as having any value. It was known as wild clover and was considered as an undesirable weed, for the reason that it was supposed to cause injurious slobbering in horses.

RANGE

It is found growing at present from New Jersey westward to Kansas, and southward, through Texas, to the Gulf. Over most of this area it grows only as a wild plant in pastures and waste places. From Tennessee and North Carolina southward it is sown for pasture and hay, but only in the alluvial valleys has it reached its greatest value.

IN TENNESSEE

As far as known, it began to be noticed in Tennessee about forty years ago, growing along roadsides, in meadows and waste places, over the western part of the State. Its value in grass pastures was soon recognized, and after a few years it was cut for hay, along with native grasses. It was not commonly sown for hay and pasture until within the last fifteen or twenty years. Its recognized value as a soil improver is of recent date.

COMMERCIAL IMPORTANCE

As a hay crop, it was first grown on an extensive scale by Col. J. B. McGhee, in Louisiana, in 1880. At present it is considered as one of the most important forage crops over a large part of its range, thriving better than any other legume on all types of soil. In Mississippi, Louisiana, Alabama, and eastern Texas it reaches its maximum usefulness. The larger part of the seed found on the market is from Louisiana and Mississippi. The general belief of most growers is that seed from the far south produces more vigorous crops than that grown farther north, but there is no conclusive proof to bear out this opinion.

HABITS

Lespedeza is an annual. The young plants come up early in the spring, make slow growth till midsummer, then develop rapidly, ripen seed, and die down after the first killing frosts. Some early varieties grown at the West Tennessee Station mature and die before the first frosts, thus showing that frost is not the limiting factor in the growth of this plant. No plants have been found which live over winter. The whole plant, including the roots, dies late in the fall. One variety grown at the Station seems to be somewhat frost-resistant, and remains green until the ground freezes. This is probably due more to the late-maturing habits of the plant than to a tendency to become a perennial. The young plants seldom appear early enough in Tennessee to be killed by late spring frosts. In West Tennessee young plants frequently appear in February, but in no case has it been observed that they are killed by frost, to which they seem to be more resistant than old plants. Where the young plants are protected by stubble of the previous year's crop, they make considerable growth before warm weather, and even where seed is sown on freshly prepared land without any protection the young plants survive late frosts.

GROWTH

The plants are upright in growth when young, but later the side branches take the lead, and they tend to become spreading, if not too closely crowded. Where the plants are very thick on the ground the side branches do not develop, the main stem taking the lead and growing to a height, varying with soil and moisture, up to 30 inches under the most favorable conditions. Where plants are alone, or the stand is thin, they spread out a foot or more in width. They rarely grow over six inches tall. In our experiments, where the plants are allowed to stand 36 inches apart, they often reach a width of three feet, and in a few cases plants have been found 42 inches across, and weighing, when dry, with all the branches and roots attached, about half a pound. The branches spreading on the ground take root at the nodes. The roots of very large plants have been found penetrating the hard clay soil to a depth of 24 inches.

FLOWERING AND SEEDING

Lespedeza begins flowering in Tennessee about the middle of July in an average season. The flowers bloom one at a time in clusters in the axils of the leaves, and may be overlooked. The number of flowers to the cluster varies from one to a dozen, and there may be flowers and ripe seed in the cluster at the same time. The flowers are about a sixteenth of an inch across, blue or purple in

color, and remain open only a short time, usually withering up the same day they bloom out. There is only one seed in a short pod to each flower. The ripe seed with its seed pod, called the husk, sheds off readily. As the husk is not easily removed, the seed are usually found on the market unhulled.

Most species of *Lespedeza* have two kinds of flowers; one kind blooms out, and the other does not. Both kinds, however, make good seed. Japan clover seems to have this habit. Mature seed are always found on the branches under the plants, near or on the ground, where apparently they have not bloomed out. In two Chinese species grown in our experiments a large part of the seed is matured from the flowers that do not open, and it is possible to distinguish the two kinds of flowers in the bud stage. As no insects have been seen visiting the flowers of *lespedeza*, it is evident that the flower is self-fertilizing.

There has been no evidence to show that there is any mixing of varieties. Several strains or varieties have been grown side by side in rows for a number of years, yet they have apparently not crossed. Attempts at artificial crossing have not succeeded. The flowers are small and delicate, and nearly always drop off when crosses are attempted. Trials at crossing *lespedeza* with other species have all failed. The two Chinese species mentioned may have been crossed naturally, as some of the plants looked like crosses of the two. They were not studied further, however, as they appeared to be of no commercial importance.

LESPEDEZA AND HOP CLOVER

Lespedeza is often confused by the farmer with hop clover. The two can be readily distinguished by the flowers and leaves and the time at which the plants develop. *Lespedeza* seed germinate in the spring and make slow growth till June, whereas hop clover seed germinate in the fall, and the young plants remain green throughout the winter. Hop clover starts growth early in the spring, the plants ripening seed and dying down before *lespedeza* makes much growth. This alone would distinguish the two plants. The leaves are about the same size, and look much alike, each consisting of three leaflets at the end of a short stalk. In *lespedeza* they stand at the same level, but in hop clover the middle leaflet is raised slightly above the two lateral leaflets. The *lespedeza* leaflet is smooth on the margins, without a notch at the end. The midrib extends slightly beyond the end of the leaflet. Hop clover leaflets are slightly broader toward the end, wedge-shaped below, and slightly toothed, and have a decided notch at the end. The flowers are very different. Those of *lespedeza* are blue or purple, and those of hop clover are yellow. *Lespedeza* flowers are on very short stalks, in clusters, while hop

clover flowers are on long flower stalks, in heads, and the flowers all bloom about the same time. The heads turn brownish without shriveling up, and remain on the plant. The dried heads resemble hops; whence the name "hop clover". The seed of lespedeza are about two-thirds the size of red clover seed, but flatter and dark in color, and remain in the seed pod, while those of hop clover are about the color and size of white clover seed, and shell out very easily. There are two common varieties of hop clover in Tennessee, and often they are found growing side by side. One is larger and somewhat later than the other. The larger is the more common. The smaller has fewer flowers, arranged in looser but smaller heads.

NATIVE SPECIES

There are a number of native species of *Lespedeza* in Tennessee, but none that resemble Japan clover sufficiently to be mistaken for it. They are all perennials. The tops die down in the fall, but the roots live over winter. They are found growing in woods and waste places; none are cultivated, as they are of no agricultural value. A few other foreign species have been imported, but none of them have proved of much value.

PLANTING

The most favorable time to plant lespedeza in Tennessee is early spring. The seed germinate rather slowly, and if sown in February will generally germinate some time in March, too late for frosts severe enough to kill the young plants. In self-seeded fields the young plants may appear in late February. Fall seeding has not been tried experimentally, but it is reasonable to believe that seeding done too late in the fall for the seed to germinate before spring might prove satisfactory. An early stand is desirable since lespedeza requires a long growing season for best results. Seedings made in this State as late as June 15 have ripened some seed, but made very poor yields of forage. It is hardly worth while to sow later than the middle of April with the expectation of getting a profitable crop the first year. One bushel (25 pounds) to the acre of good seed in the husk is usually sufficient to insure a good crop for hay or pasture the first year. If it is desired to get only enough plants to reseed the ground, a smaller amount may be used. Even one peck to the acre will produce enough to reseed the ground completely. Trials at the West Tennessee Station have shown that one bushel to the acre gives better results than either more or less than this amount.

The seed are sown broadcast, either by hand or with a clover seeder. A clover seed drill opened wide has been found very good for planting lespedeza. The covering of the seed should be very light. If covered more than one-fourth inch they may not come up to a

stand. A good rain following broadcasting of the seed will generally effect all the covering that is desirable. If a drill is used it should be set very shallow. Running over the ground with a roller of the cultipacker type after sowing the seed has been found at the Station to cover the seed sufficiently, and at the same time pack the land into a good, firm seed-bed, which is very desirable.

PREPARATION OF THE LAND

The land should be well prepared before planting. It should be broken if hard, disked and harrowed, and brought to a fine seed-bed. At least as good preparation should be given as for either red clover or alfalfa. When lespedeza is to be sown on other crops, oats or redtop, for example, the land should be gone over lightly with a harrow before seeding, and possibly harrowed again after seeding. This will not injure the oats or grass seriously, and will insure a good stand of lespedeza.

HARVESTING

The best time for harvesting lespedeza depends upon the purpose for which it is harvested.

If cut for hay, the best time is when the plants are full-grown, but before the leaves begin to shed. This will depend upon the season, but will usually be in September or early October. A part of the seeds will be ripe at this time, but there will still be flowers at the tops of the plants. It has been found best to cut the hay in the morning after the dew is off and rake it into windrows in the afternoon of the same day. It may be left to finish curing in the windrows or put up in shocks the following day and left there to finish curing. The per cent of moisture in lespedeza is low, and curing takes place very quickly in the shock. If the weather is damp the rack used in curing alfalfa hay can be used to advantage. Some of the most careful lespedeza growers use hay caps to protect the hay against rain, and also to preserve the green color, as sunburned, or brown, hay is less desirable and brings a lower price on the market. The hay is of better quality if allowed to cure in bulk rather than in the swath after the mower. It not only is brighter and greener, but is said to be more palatable to stock on account of the aroma imparted to it by curing in bulk. The leaves are also preserved on the stalk. Hay which consists mostly of stems has a very poor sale on the market. Lespedeza should be handled as little as possible because of the tendency of the leaves to shatter off.

If the crop is to be cut for seed it should be left till most of the seed are ripe, generally, in Tennessee, about the time of the first killing frosts, or the middle of October. Some of the leaves will have dropped off at this time and the stems will be more woody. The

cutting should be done with a good mower, having a very sharp blade, and before the dew is off in the morning. The hay is raked into windrows in the afternoon and shocked the same day if possible. The shocks should be capped and allowed to stand till dry. The smallest possible amount of handling is best, since lespedeza seed shatter more readily than those of any other legume.

COLLECTING SEED

In the far south, where much of the commercial seed is grown, the hay is threshed on a grain thresher with special lespedeza attachments, or with the concaves removed. The farmer can get all the seed needed for his own use by beating the hay on a tight floor or a sheet, and fanning the leaves and dirt out with a good fanning mill. The hay may be hauled on a frame with a tight bottom, and a considerable amount of seed collected in this way. Some farmers get enough seed on the floor of the barn loft after the hay is removed to supply their needs.

Another method of collecting the seed is known as the seed-pan method. A specially constructed pan of galvanized iron is bolted on the cutter bar, and drags behind the blade. The pan is as long as the blade and about 30 inches wide. It has a lid of corrugated metal hinged at the front so that it may be opened to remove the seed. The lid is perforated with half-inch holes at the bottom of the corrugations for the seed and leaves to fall through into the pan. These are taken out at intervals and sacked and allowed to dry, or spread out to dry, then cleaned by fanning once or twice. Seed collected in this way are of better quality than threshed seed, because only mature seed are obtained in cutting the hay. The seed pan may be used to advantage when cutting lespedeza for hay, as a good portion of the seed will be ripe at this time. One can judge of the amount of ripe seed by the amount collecting on the cutter bar of the mower. Enough seed will be shattered off to reseed the ground even when the seed pan is used, if there is enough ripe seed to justify the use of the pan. At present very little, if any, lespedeza is threshed in Tennessee, but there is no reason why it could not be threshed. Many farmers are gathering enough seed for their own use, and some for their neighbors, by the pan method.

The weight of a bushel of well-cleaned lespedeza seed in the husk is 25 pounds. No one has used a huller to clean the seed. A clover seed huller probably could be used, but it is a question whether this would pay, as the seed is easily handled in the husk.

In Louisiana an attachment is used for bunching the hay as it is cut. This is on the order of the old-fashioned grain reaper. The farmers of Middle Tennessee use a machine constructed on this plan for harvesting ripe crimson clover. This might prove to be a good

machine with which to harvest lespedeza. If a combination of the seed-pan and bunching machine were on the market, it might be of great value in harvesting lespedeza seed, but so far no such machine is known. The main difficulty in using such a machine would be in removing the seed from the pan, which has to be done at frequent intervals. When the seed pan is used an extra man is required to keep the hay raked off the pan, and this at best is no easy matter. If the lespedeza is mixed with crabgrass, as is often the case, cutting is very difficult at the time of harvesting for seed. The construction of the seed pan used at the Station is shown in the accompanying picture (page 27). This pan is manufactured by a firm in Baton Rouge. Some makes have a number of iron rods across the pan instead of the lid shown in the illustration.

HAY CAPS

Hay caps are usually made of cotton sheeting about three or four feet square. Sheeting is better than canvas because it gives all the protection necessary against rain, and allows the moisture from the hay to escape. It is not necessary to cover more than the top of the shock. The caps must be fastened to prevent their being blown off. Various means are used for this purpose. Sticks may be tied to the corners, and thrust into the shocks, or weights may be tied in the corners. Considerable care has to be taken in fastening the caps.

GERMINATION

Well-matured seed give a high per cent of germination when fresh, but the germination decreases rapidly when the seed are kept over. An experiment made at the Station with seed one and two years old showed that one-year-old seed, out of ten samples taken, gave germinations of from 32 to 80 per cent, while two-year-old seed gave only from 12 to 64 per cent. Seed three years old gave much lower results, but a few seed will remain germinable longer than three years. In 1920, seed from the 1915 crop were sown thick in rows. A few plants came up late. It is not safe to sow seed more than two years old, and if two-year-old seed have to be used the amount should be doubled. In all samples tested there were a few hard seed left on the germinator at the end of the experiment.

Experiments carried on at the Louisiana Station¹ showed that three-year-old seed failed to germinate, and two-year-old seed gave a low germination. In each case the hard seed left over germinated when tested later. It was also found that seed treated with sulphuric acid germinated very rapidly, within three or four days. At the Tennessee Station seed have never been found coming up the second year after planting. Tests were made by placing seed in the

ground at different depths. They were dug up at intervals and examined. After one year, all the seed placed deeper than one inch below the surface were decayed, with the exception of a few hard seed, which failed to germinate when tested in the laboratory. The trial was continued for three years, and a few hard seed were found at the end of that time.

INOCULATION

Lespedeza, like other legumes, has nodules produced by certain soil bacteria, which gather nitrogen from the air and store it in these nodules in the form of nitrogenous compounds. The bacteria penetrate the roots, increase rapidly in number, and, at the points where they are located, stimulate the growth of the roots, thus forming the nodules. These nodules, which are small knot-like growths, or tubercles, of varying sizes, the largest being about the size of a small pea, can be observed on the roots of the plants wherever the latter are found. The nodules decay, and the nitrogen is either taken up by the plant for its own growth or left in the soil to be used by future crops. Since lespedeza is inoculated wherever found, these bacteria would seem to be very common in our soils.

Burrill and Hansen² divide the nodule bacteria into nine groups according to the legumes upon which they grow. They found, for example, that the bacteria in lespedeza nodules attack the native species of *Lespedeza*, cowpeas, peanuts, velvet beans, beggarweed, and a number of other wild legumes; that is, bacteria from any one of these plants will produce nodules on any other. They found that the several varieties of red clover, alsike, crimson, and white clover constitute another group; the common garden peas, field peas, vetches, and sweet peas, another; and garden and scarlet runner beans still another. They found that soybeans stand alone, being inoculated by bacteria which do not attack any other legume. These experiments did not include all the common legumes, wild and cultivated, but the authors explain why some soils are inoculated for some legumes and not for others. They also explain why a plant like lespedeza is so commonly inoculated, there being few soils in which some of the plants of its group have not been growing recently.

Garman and Didlake³ make the assertion that cowpeas are not inoculated by the bacteria found on any other plants. *Lespedeza*, however, was not included in their trials.

AMOUNT OF NITROGEN GATHERED

The amount of nitrogen assimilated by lespedeza is considerable. Dodson⁴ found that 76 per cent of the dry weight of the whole plant

is usually cut for hay, leaving 24 per cent of stubble, roots and leaves on the ground. Chemical analysis showed that 1.65 per cent of the roots and stubble and 2.28 per cent of the stems and leaves were nitrogen. Some of the nitrogen left in the soil is lost by leaching, and perhaps otherwise. As some nitrogen is taken by the plant from the soil itself, it is doubtful if more would be added than is taken from the soil when the hay is removed; but when the whole crop is turned under the increase in fertility is shown by the increased yields in crops following it. According to Dodson's calculations, when an acre of ground yields three tons of hay there will be one ton of stubble and leaves left on the ground. Counting 1.65 per cent of this as nitrogen gives a total of 33 pounds of nitrogen to the acre, nearly as much as is furnished by 500 pounds of high-grade cottonseed meal. If the whole crop were turned under it would be equivalent to about 2500 pounds of cottonseed meal. In addition to this, the physical condition of the soil is much improved by the lespedeza.

YIELDS OF HAY AND SEED

The amount of hay harvested from a lespedeza field will depend upon the soil, the season, the time of sowing, and the stand. It is commonly said among farmers that each four inches in height of a good stand will make a ton of hay to the acre. The fact is that lespedeza makes a surprisingly large yield, considering the appearance of the field. This is accounted for by the very thick stand, together with the small amount of water in the plants. Unless the stand is at least six inches tall, mowing is hardly advisable, as the blade will run over much of a short stand. One or two tons of dry hay is common, while three or four tons to the acre is not unusual on good land. In a few instances, on certain fertile bottom lands in West Tennessee, as much as five tons is said to have been obtained. In such cases the stand is pure lespedeza and very tall, 24 inches or more.

The yields of seed vary considerably. Frequently where the hay yield is very large the amount of seed obtained is small. The most seed is made by a fair stand on moderately good soil. Half a bushel of seed sown on an acre will produce more seed than a very heavy seeding. The Station plots were found to yield from four or five bushels up to twenty bushels in exceptional cases. Our No. 76 has yielded an average of about six bushels to the acre, collected with the seed pan, and not threshed, and enough was left on the ground for reseeding.

INFLUENCE OF LIME AND FERTILIZERS

In the spring of 1914, a range of ten one-fortieth-acre plots was laid off on thin gray land of the West Tennessee Station. One-half of each plot was limed with ground limestone at the rate of two tons per acre. The plots were fertilized according to the plan given in Table 1. The hay was mowed about the middle of October and weighed green each year for three years. A computation of the hay yield was made from a five-pound sample taken from each half plot, and thoroughly dried and weighed again. No other lime or fertilizer was added after the first application. The stand of lespedeza was better the last two years than the first. The hay yields of each half plot estimated in pounds per acre are given in Table 1.

TABLE 1.—FERTILIZER AND LIME EXPERIMENTS WITH LESPEDEZA

Plot	Fertilizer per acre in pounds	Yields of hay per acre in pounds					
		1914		1915		1916	
		Limed	Unlimed	Limed	Unlimed	Limed	Unlimed
1	None	1728	512	3808	2272	3072	2688
2	1000 lbs. acid phosphate	1504	608	3840	3968	4288	3840
3	500 lbs. muriate potash	1344	832	3968	2368	3456	2688
4	100 lbs. nitrate soda	1312	416	2976	2272	3616	2496
5	None	2016	1248	3520	2400	3904	3040
6	1000 lbs. acid phosphate 500 lbs. muriate potash	1152	960	3840	3488	5440	4032
7	1000 lbs. acid phosphate 100 lbs. nitrate soda	2560	1440	4960	3200	5536	4544
8	500 lbs. muriate potash 100 lbs. nitrate soda	1024	928	3488	2752	5568	4864
9	None	2508	2016	4320	2976	5760	4832
10	1000 lbs. acid phosphate 500 lbs. muriate potash 100 lbs. nitrate soda	1536	1248	4320	4320	5568	5440
Average gain per plot of limed over unlimed		647		902		794	
Per cent of gain		63		30		20	

It will be observed that on this soil commercial fertilizers did not influence the yields to an appreciable extent, but that the increase from lime is marked, although it drops off from year to year. Similar results were obtained in other trials on this farm. At other stations it has been found that acid phosphate did increase the yields.

For example, at the Water Valley branch station of Mississippi it was found that the addition of 400 pounds of acid phosphate nearly doubled the yield of hay.⁵

SOIL RENOVATION

There is no doubt that lespedeza greatly improves old and worn soils. Many old, abandoned fields in the western part of the State have been brought back to a state of cultivation by the growth of lespedeza which came in naturally. One of the chief values of lespedeza is in the fact that no soils are too poor to make some growth, not even the clay of gully banks where little else will grow. With its nitrogen-gathering powers, it gradually builds up the land, and at the same time checks erosion until other crops can thrive. Old lespedeza fields are found very desirable for cotton and corn, not only on account of the fertility, but of the improved mechanical condition of the soil. It is a well-known fact among farmers that lespedeza lands bring a relatively high rental. The claim is made that they produce a higher grade of cotton than other lands. The same is true with regard to tobacco. Why the quality of the crops following lespedeza is improved is not clearly understood, but there is a general belief that such is the case.

PASTURES AND LESPEDEZA MIXTURES

There is no doubt in the minds of farmers that lespedeza makes a good pasture, whether grown alone or in a mixture with grass. The carrying power of many pastures may be increased 25 per cent or more by the addition of lespedeza. The main objection to a pure lespedeza pasture is that it comes on very late in the spring. This disadvantage is removed when it is sown in a mixture with grasses that make an early pasture, especially as lespedeza stays green late in the fall after the grasses are exhausted. In combination with bermuda, bluegrass, or redtop it makes an ideal pasture for horses, cattle, and sheep; but it is objected to somewhat as a hog pasture on the ground that it becomes too tough in the fall. There are very few pastures which do not contain lespedeza as a constituent.

The objection previously mentioned that it causes slobbering is not serious, since slobbering ceases after a few days, when the animals have become accustomed to this kind of feed. It is thought by some observers that slobbering is not caused by lespedeza, but by hop clover. There seems, however, to be little doubt that lespedeza will cause slobbering in some cases. This is true of other closely related plants as well, especially white clover and alsike.

Lespedeza and redtop sown together will not only make a good all-season pasture, but will make two good hay crops in a season, the redtop being cut in June, and the lespedeza in October. Bermuda

and lespedeza also make an excellent permanent pasture. In some parts of the South carpet grass is used instead of bermuda. It has about the same habits as bermuda, but is not grown in Tennessee. Crabgrass appears in most lespedeza pastures. This mixture makes a good pasture, and the crabgrass adds materially to the yield of hay. Redtop and lespedeza are both sown in the spring in Tennessee, and both crops will continue until broomsedge comes in and spoils the pasture.

IN ROTATION

Many combinations of lespedeza with other crops may be made for the purpose of rotation. One favorite rotation with farmers in the far South is oats and lespedeza. The oats may be sown in the fall and lespedeza the following spring. After that, lespedeza will perpetuate itself. It is necessary only to disk the lespedeza stubble as a preparation for sowing oats in the fall. A three-year rotation of corn, oats, and lespedeza is also a favorite one. The first year corn is harvested; the second year oats and lespedeza are harvested; the third year lespedeza alone is harvested or turned under for corn the fourth year.

Cotton may be substituted for corn the fourth year, thus making a corn, oats, lespedeza, and cotton rotation. The advantage of oats and lespedeza in these rotations is that they are both quickly harvested, at a time when other farm work is slack, the oats in May or June and the lespedeza in October. These rotations provide for money crops, such as are grown in the South, and a legume to plow under for improvement of the soil. Lespedeza may be allowed to stand more than two years, thus extending the rotation to any length. Mr. A. D. McNair⁶ outlines two systems of rotation suited to the South. These are given in Tables 2 and 3.

TABLE 2—A FOUR-YEAR ROTATION OF COTTON, CORN, OATS
AND LESPEDEZA

Year	First field	Second field	Third field	Fourth field
First	Cotton	Corn with cowpeas	Oats followed by lespedeza	Lespedeza
Second	Corn with cowpeas	Oats followed by lespedeza	Lespedeza	Cotton
Third	Oats followed by lespedeza	Lespedeza	Cotton	Corn with cowpeas
Fourth	Lespedeza	Cotton	Corn with cowpeas	Oats followed by lespedeza

In the rotation given in Table 2 cowpeas are to be planted between the corn rows. Here we have six crops, counting cowpeas, in four years: one money crop—cotton; two cereals for money or feed—corn and oats; two hay crops for money or feed—lespedeza; and a pasture or fertilizer crop—cowpeas. Lespedeza is also a fertilizer crop. By dividing the farm into four fields it is possible to obtain all six crops each year.

TABLE 3—A FOUR-YEAR ROTATION FOR A DAIRY FARM, WITH LESPEDEZA FOR HAY AND PASTURE

Year	First field	Second field	Third field	Fourth field
First	Corn with cowpeas	Soybeans or peanuts	Oats and lespedeza	Lespedeza
Second	Soybeans or peanuts	Oats and lespedeza	Lespedeza	Corn and cowpeas
Third	Oats and lespedeza	Lespedeza	Corn and cowpeas	Soybeans or peanuts
Fourth	Lespedeza	Corn and cowpeas	Soybeans or peanuts	Oats and lespedeza

A four-year rotation of corn, oats and lespedeza, has been maintained at the West Tennessee Experiment Station for a number of years, as follows: First year, corn; second year, oats and lespedeza; third and fourth years, lespedeza. The land had been in lespedeza three years before the first crop of corn. On another range, corn has been grown continuously. The yields of corn from representative plots of both ranges are given in Table 4. The plots were fertilized as indicated each year for the whole period.

The following four-year rotation used by Mr. W. N. McFadden, Warren, Tennessee, has been found very satisfactory:

1st year—Corn or cotton.

2d year—Oats, seeded to redtop and lespedeza.

3d year—Hay (redtop and lespedeza).

4th year—Pasture.

WEEDS

In newly sown lespedeza, weeds are likely to grow rank and overtop the lespedeza, especially on fertile lands, or, when the stand is thin, on any kind of soil. To overcome this trouble the weeds should be mowed once or twice before the middle of summer. After

TABLE 4—COMPARISON OF CONTINUOUS CORN WITH ROTATIONS OF CORN, OATS, AND LESPEDEZA

Range	Plot	Rotation	Fertilizer	Yields of corn in bushels per acre		
				1912	1916	1920
1	13	Corn	5 tons manure			
			200 lbs. acid phosphate			
			50 lbs. muriate potash	55.35	48.50	63.57
			67 lbs. nitrate soda			
	14		5 tons manure	54.28	45.00	48.92
	15		None	40.71	33.50	26.42
	17		None	47.14	28.50	27.85
2	23	1st year Corn	None	54.18	55.70	70.35
	26	2d year Oats and lespedeza	None	57.20	56.75	80.56
		3d year Lespedeza	200 lbs. acid phosphate 50 lbs. muriate potash	56.40	53.90	94.62
	28	4th year Lespedeza	None	54.80	49.25	79.64

that the lespedeza will make such rapid growth that the weeds will be held in check. The most common weed in this section is crabgrass; but in wet lands smartweed gives much trouble. The second year the stand of lespedeza is usually thick enough to take care of the weed situation. In very thin soils, the so-called "poor John" is a very common weed, its habit of growth being somewhat similar to that of lespedeza. Crabgrass, unless too abundant, does not damage the quality of the hay seriously. In old pasture mixtures, the grass commonly called broomsedge will become so plentiful as to necessitate the plowing up of the pasture.

The well-known clover dodder may be very troublesome in lespedeza in some seasons. Unless taken in hand early in the season, when it first makes its appearance, it is very difficult to eradicate. Hand-picking will destroy it if done early and thoroughly, and as often as the dodder becomes noticeable. It is readily identified by the bright yellow thread-like vines running over the plants. As the dodder is attached to the plant, the part bearing it, or better, the whole plant, should be removed from the field. Where dodder is in large patches in the field all the plants within these spots should be hoed up and piled into heaps, with the dirt dug up, in the middle

of the spots, in order to kill the dodder. Dodder seed are not very common in lespedeza seed, especially if the seed are collected by the pan method, as they do not shatter off when the hay is cut. Lespedeza or clover containing dodder should not be harvested for seed.

ENEMIES

Lespedeza is practically free from fungous or bacterial diseases, such as attack other legumes. Occasionally, a small patch of a peculiar bluish moldy appearance is found, caused by a slime mold that is frequently found on lawns. This does very little damage to the crop. A common mildew is often found growing on the leaves, but this disease is unimportant in Tennessee. Insect attacks are also rare. Grasshoppers cause some damage, but this is slight. The larva of the smoky crane fly (*Tipula infuscata*) is reported to have completely destroyed a stand in a field in Madison County in 1908.⁷ This insect is common in that section, but it has not been observed causing trouble since the date mentioned. It is well known in the adult stage as a large, long-legged, mosquito-like insect, swarming around grass and clover fields in the fall. The larva, called a grub or maggot, lives in the soil and subsists on the roots of legumes and other plants. The damage reported occurred in the month of March, when lespedeza plants are very small.

IMPROVED VARIETIES

In the fall of 1912, work was begun at the Tennessee Agricultural Experiment Station on the life-history, habits, and improvement of lespedeza. The project was later extended to include a study of its adaptation to uses as a hay and pasture plant, and as a soil improver, on the various types of soil of the State.

Two hundred and fifty-eight selections of seed were made, some from single plants, some from groups of plants growing wild, and some from the fields of lespedeza grown from market seed. These seed selections were sown in rows 24 inches apart, on the West Tennessee Station farm, in the spring of 1913 (page 20). The rows were cultivated to keep the weeds out, and close observations were made throughout the season. Differences between the selections were soon apparent. The seed of some selections germinated much earlier than those of other selections; the plants of some were larger; of others earlier; and there were variations in color. All had the spreading habit of the commonly grown variety.

Seed were selected again from all these rows, and sown in rows and plots the following spring. The rows were placed 36 inches apart, and the plants the same distance apart in the row, thus giv-



Lespedeza Selections in Rows.

Lespedeza Selections in Plots. Stakes are Same Height.

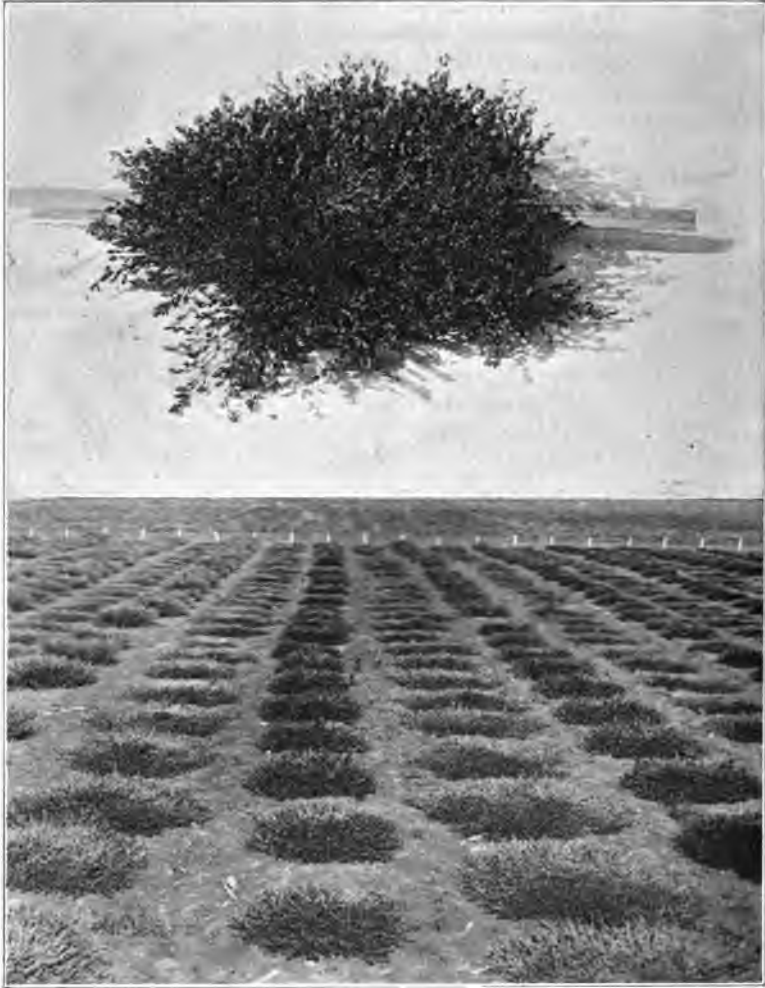
ing each plant opportunity to grow without interference. This was done in order that the individual differences of single plants might be studied. The plots were treated about the same as ordinary fields of lespedeza, except that the weeds were kept out.

Differences between the selections as to size and earliness were again very marked. The plants in rows grew to a very large size, a few of them being 42 inches across. With one exception they were of the usual spreading type. In No. 89 there was one plant rather bunchy instead of spreading, and with many fine branches and many leaves. This plant was so different from any other in the plot that it was selected for further study. Another selection, No. 46, was much larger than any other, and it was selected as a good type of the spreading plant. No other rows showed any remarkable characteristics. A large number of selections were discarded that year because they were much alike, or else too small to be of any value. The plots showed the same differences as to size, earliness, and color that the rows showed the previous year. Some of the selections made large yields of hay compared with others. Some were so short that they were not thought to be worth harvesting. The seed yields varied as widely as the hay yields.

The following year all the remainder of the selections were planted in rows both at Knoxville and at Jackson. From this time on, with a few exceptions, rows represented single plants of the previous year. The plants in the row from the bunchy plant, No. 89, were all like the mother plant. A new variation appeared in No. 76. Five plants at Knoxville, in one row, and two plants at Jackson, in a plot, were different from any others. They were taller, nearly upright in growth, and held all the branches up off the ground.

Seed were gathered from each of these seven plants for progeny rows the following year. The bunchy plants from No. 89 and the upright plants from No. 76 were given these numbers, respectively, and have been carried on as new varieties since that time under these numbers. They have remained true to type in a remarkable degree, and are easily distinguished from all other selections either in rows or in plots. Many other slight variations have appeared in other selections, but they have been so nearly like the common variety that they have been discarded. Only the best one of the common spreading types has been kept in the experiment. This is No. 46, previously mentioned.

In the fall of 1915, a search was made in the Smoky Mountains of Sevier and Blount Counties for stray plants of lespedeza. The plant grows abundantly in the valleys of those counties, but as the elevation increases it gradually disappears. A few plants with ripe seed were found at Indian Gap, just over the state line, in North Carolina, at an elevation of about 4500 feet.



Original Plant of the New Variety No. 89.

No. 89 in Center and Second Row to Right. Dark Color Indicates Frost-Resistance.

The seed were planted in rows at Jackson the following year. The progeny of only one plant differed enough from the ordinary kind to be thought worth keeping. They were of the usual spreading type, but developed very early in the spring, flowering, ripening seed, and dying some weeks ahead of the other selections. While the plants are rather small, and of no importance in most sections of the State, this variety was kept and propagated as, possibly being suited for sections north of the present range of lespedeza, and in high and cool parts of the State. It will not be valuable except in pasture mixtures and for soil improvement where other legumes are not suited for those purposes. This variety has been designated as "M".

The three varieties, No. 89, No. 76, and M, have been kept and propagated for comparison with No. 46, a good type of the large, spreading kind. They have been sown in ranges large enough for comparison as to their value for hay and for pasture. No. 76 makes from one-third to one-half more hay than either of the others. No. 46 ranks second. No. 89, while third, makes an abundance of fine pasture, and remains green till killing frost. Nos. 76 and 46 make large yields of seed, while No. 89 makes only enough to reseed the land well, about a bushel to the acre, collected with the seed pan. M makes a good crop of seed, but is too short to cut with profit.

DESCRIPTION OF FOUR VARIETIES*

No. 46. Plants spreading when growing alone, central stem short, branches long, lying on the ground, and taking root at the nodes, many small branches forming a mat on the ground. Branches turn upward at the ends. Plants upright when grown close together, the central stem taking the lead in growth. Begins flowering about the middle of July, and ripens an abundance of seed by frost. Useful as a hay and pasture plant.

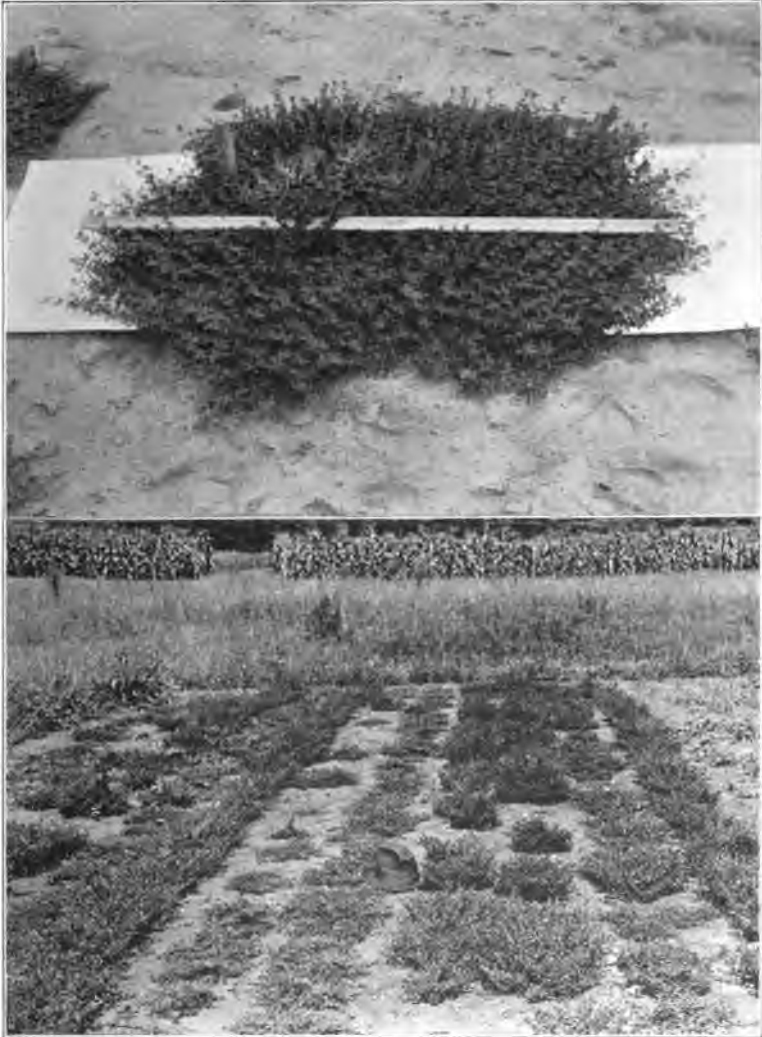
No. 89. Plants bunchy when grown alone, branches numerous and short, very leafy. Central stem very short. Flowers late, and makes few seed. Somewhat frost-resistant. The original selection was made in a hay field in Gibson County, grown from commercial seed; origin not known. Plants upright when grown thick. Makes only a fair yield of hay. This is considered a good pasture variety because of its lateness and leafy habit.

No. 76. Plants tall when grown alone; branches numerous, ascending, held up off the ground, and shorter than branches of No. 46. Flowers from the middle of July till frost, and ripens an abundance of seed. In thick seedings it grows much taller than any other variety, and makes, on the average, a third more hay. Well adapted for hay and pasture. The original selection was made in a

*These are considered as varieties only in an agricultural, not a botanical sense.



Plants of No. 76, a New Upright Variety. Height 14 Inches.
Rows of No. 76 Contrasted with Rows of Spreading Plants.
Thickly Sown Plot of No. 76. Stake in Center 18 Inches High.



A Single Plant of the Spreading Type, 42 Inches Wide, as Shown by Yardstick.

Varieties of Lespedeza in Rows. Left to Right, Beginning at Corner:
76, 46 (4-Year-Old Seed), M, 76, 76, 89, 76.

field in Henderson County, mixed with native grasses. Lespedeza had never been sown in that neighborhood; hence the origin of this selection is not known.

M. Plants have the general character of No. 46, but are about half its size. Begins flowering in June, and ripens a good crop of seed and dies before frost. The original selection was made in Swain County, North Carolina, at an elevation of about 4500 feet. This variety is adapted to sections having a short growing season, but will not compete with the larger varieties in other sections.

OTHER NEW AND IMPROVED VARIETIES

From time to time new varieties have been reported. About two years ago a large and improved variety was reported from South Carolina, but it has not been described. Gerald McCarthy, Botanist of the North Carolina Agricultural Experiment Station, reported in 1895 a broad-leaved variety, which he named *Lespedeza striata* var. *lata*.⁸ He described it as a broad-leaved and stronger-growing variety of the common Japan clover. The two varieties were grown side by side, and the broad-leaved variety showed such superiority over the old variety that he recommended that the latter be discarded and only the former be grown. It is described as creeping and growing in flat rosettes on the ground, producing seed at the same time, and in about the same quantities as the common variety. The variety seems to have been lost. An inquiry sent to the North Carolina Station brought the reply that no such variety is now grown at the Station. The pictures in McCarthy's publication show that his variety is different from our new varieties. The broad-leaved strain has not appeared in any of our selections.

THE PLACE OF LESPEDEZA

Lespedeza, while a very useful crop plant, has limitations as well as advantages. It will not take the place of alfalfa and the clovers, cowpeas, or soybeans. It will grow, however, in many situations where the others fail. Stands can be secured under widely varying conditions. It grows well on fertile or thin soils, acid or alkaline, dry or wet; but does best, of course, on fertile and well-drained soils, with plenty of lime. It will grow on more poorly drained soils than any other common legume. It spreads rapidly and naturally into new territory, reseeding itself, which is not true of the other crops mentioned. It stands drought well, and will recover quickly after a drought. It furnishes an abundance of good pasture where the other legumes could not be depended upon. Yields of hay compare very favorably with those from the other legumes, and it requires but one cutting a season, whereas alfalfa and red



Seed Pan Opened for Removal of Seed.

Field of No. 76 Harvested for Seed. Hay Cut with Dew On and Raked into Windrows.

clover are cut twice or oftener. The harvest time is at a season when the weather is favorable for hay-curing, and other farm work is not urgent. In quality and feeding value the hay is about equal to that of alfalfa and red clover. There is no longer any doubt that lespedeza is a valuable soil improver.

On the other hand, it has certain disadvantages. It is late in developing, and is smaller than the other crops. If harvested at the time when the best hay is obtained it may fail to reseed itself, especially if the stand is very thick. A second crop is seldom obtained the same season, although enough growth may be made to reseed if the season is favorable.

Lespedeza is never a pest, as it is easily killed by cultivation.

REFERENCES

1. Dworak, Mayme. Lespedeza seed. 1916. La. Agr. Col. Div. Ext. Cir. 11.
2. Burrill, Thomas J., and Hansen, Roy, 1917. Is symbiosis possible between legume bacteria and non-legume plants? Ill. Agr. Exp. Sta. Bul. 202.
3. Garman, H., and Didlake, Mary. 1914. Six different species of nodule bacteria. Ky. Agr. Exp. Sta. Bul. 184.
4. Dodson, W. R., and others. 1911. Lespedeza or Japan clover. La. Agr. Exp. Sta. Bul. 130.
5. Ames, C. T. 1914. Report of work done at Holly Springs branch station, 1913. Miss. Agr. Exp. Sta. Bul. 165.
6. McNair, A. D., and Mercier, W. B. 1911. Lespedeza or Japan clover. Farmers' Bul. 441.
7. Hyslop, James A. 1910. Bu. Ent., U. S. Dept. Agr. Bul. No. 85, pt. 7.
8. McCarthy, Gerald. 1896. Some new forage, fiber, and other useful plants. N. C. Agr. Exp. Sta. Bul. 133.

OTHER PUBLICATIONS USED IN THE PREPARATION OF THIS BULLETIN

- Tracy, S. M. 1892. Grasses and forage plants. Miss. Agr. Exp. Sta. Bul. 20.
- Tracy, S. M. 1920. Forage crops for the cotton belt. Farmers' Bul. 1125.
- Lloyd, E. R. 1898. Winter and summer pasture in Mississippi. Miss. Agr. Exp. Sta. Bul. 50.
- Dodson, W. R. 1902. Forage crops, grasses, alfalfa, clovers, etc. La. Agr. Exp. Sta. Bul. 72.
- Ferris, E. B. 1917. Pasture and forage crops in South Mississippi. Miss. Agr. Exp. Sta. Bul. 180.
- McCarthy, Gerald, and Emery, F. E. 1894. Some leguminous crops and their economic value. N. C. Agr. Exp. Sta. Bul. 98.
- McCarthy, Gerald. 1890. N. C. Agr. Exp. Sta. Bul. 70.

1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100.

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Knoxville

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MAY, 1921

PLANTING RATES AND SPACING OF CORN
WITH TABLES FOR PRACTICAL USE

BY
C. A. MOOERS



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Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

STOCKER CATTLE PROBLEMS

On the Cumblerland Plateau

BY
C. A. WILLSON

SUMMARY

1. Regardless of the age of the cattle on experiment, when they received silage during the winter, either in half-ration quantities or in full-ration quantities, with 1 to 2 pounds of cottonseed meal, they made more gains for the entire year than when fed the ordinary Plateau wintering ration of rough feed.

2. The cattle that were fed a half ration of silage and 2 pounds of cottonseed meal daily during the winter months made the best gains for the entire year.

3. Where a small amount of hay, up to 5 pounds daily, was used to replace one pound of cottonseed meal, the cattle did not do as well for the entire year as when fed 2 pounds of cottonseed meal daily during the winter months.

4. As compared with the Plateau "dry-feed" method, the average increase in the yearly gains from the half-ration silage and 2 pounds cottonseed meal during the winter months, was, for the yearlings, 49.7 pounds; for the two-year-olds, 55.1 pounds; and for the three-year-olds, 70.0 pounds.

5. Cattle on the Plateau, when not fed during the latter part of October and November, shrink on the average about 50 pounds. The winter feeding of cattle on the Plateau should begin the second week in November, instead of the first week in December, when the cattle come up for feed.

6. The average gain for the entire year for yearlings was 208.7 pounds; for the two-year-olds, 271.9 pounds; and for the three-year-olds, 240.1 pounds.

7. The largest summer gains for each class of cattle were made when there was the greatest winter loss. The greatest gains for the entire year, however, were made when the cattle made some gain during the winter months. Stocker cattle should be so fed that they make some gain during the winter period. It is likely that a gain of 75 pounds, or less, would be within the limits of good practice.

8. Cattle that were wintered on 15 pounds silage and 2 pounds cottonseed meal made from 15 to 32 per cent better gains for the entire year than those wintered on wild hay and other rough feed.

INTRODUCTION

The earliest method of growing cattle on the Cumberland Plateau was that of ranging them, which was practiced by the farmers of the adjoining valleys. Cattle were produced and wintered in the valleys, and driven to the Plateau and herded and salted during the fore part of the summer pasture season, until they became accustomed to a locality, after which they would range within fairly definite areas. As the Plateau became settled, many cattle were produced, as it was found that a livelihood could be much more readily gained through the grazing of cattle on the range than by any other method of farming. In former years cattle were raised extensively on the Plateau. They were afterward reduced in number, owing possibly to the opening up of the cheap western lands in the latter part of the past century. During the last decade larger areas have been cleared, and as the value of cattle has risen there is a renewal of interest in cattle raising.

Owing to the increase in the number of cattle owned on the Plateau, the range is being less used by the people of the adjoining valleys. Another reason for the decreasing use of the range by the valley farmers is that a 700-pound steer at present prices is worth from \$50 to \$60, and is therefore too valuable an animal to allow to range at will, with the risk of his straying away.

The common practice in the growing of cattle on the Plateau has been to have the calves dropped in spring, confine them in lot, and let the cow come up at night. The cow is partly milked and then turned in with the calf. The calf is allowed to run at large for the night, and the cow is kept up until morning, when she is again partly milked and turned to the range, the calf being kept in during the day. The calf is often sold before the first winter to valley or stock farmers. When kept on the Plateau the calf is fed some of the best roughage, and when necessary a little grain, and is run in enclosed fields, and browsed on aftermath, cornstalks, and similar grazing. During the succeeding years the steers and heifers receive practically no grain. They spend from April to November on the range and in the winter are fed low-grade hays and allowed to run on nearby range during the daytime. The roughages used are low in food value, and the result is that the cattle lose heavily in flesh during the winter seasons, and four years are required to develop a feeder steer.

During the period of low prices for cattle little interest was taken in their improvement, and but little was known regarding the improved breeds. It was common for Plateau farmers to describe their best animal as a "good red calf." No breed distinctions were made. During the past ten years there has been a great awakening of interest in the improved breeds of beef cattle. Purebred bulls of practically all the breeds are being purchased and distributed throughout the Plateau, and there is a marked improvement of the common cattle, so that it is now possible to select good carloads of feeders.

The Plateau offers remarkable advantages for the production of feeder and stocker cattle because of the extensive open range, where cattle are grazed without cost during the summer months. The problem of the Plateau farmer is that of wintering his cattle, and this is the limiting factor as regards the number that can be ranged.

OBJECT OF THE EXPERIMENTS

The experiments outlined in this bulletin were begun and carried out, in co-operation with Mr. J. E. Converse, on his farm six miles from Crossville, with a view to working out improved methods of wintering cattle and testing methods in vogue on the Plateau. Mr. Converse was well fitted for this work, having spent five years on the Experiment Station farm at Knoxville and twelve years supervising soil and crop experiments on the Cumberland Plateau.

EQUIPMENT

The barn used in connection with these experiments for the past four years is 74x40 feet, with stabling below and a loft for hay above. It is constructed of rough lumber, such as is easily obtained on the Plateau, and did not cost over \$500. It stabled during the winter of 1918-19, 65 head of cattle and horses. The silo* is what is known as the Tennessee wood-hoop silo. It is 12x28 feet, is constructed of white oak hoops and rough 4- and 6-inch white oak lumber, two layers, with tar paper between, and is estimated to have cost in money outlay about \$65. The stabling is well arranged for dividing the groups into lots for experimental feeding.

CATTLE USED

The cattle used in these experiments were purchased on the Plateau. During the first two years they were of poor to medium market grade classes, but during the remaining years were of good quality. The cattle used in the winter of 1915-16 were purchased at an average of \$39 per head, and were carried through the summer of 1916, when one-half of them were sold at an average of \$55 per head, or 5½ cents per pound. The remaining one-half were carried through the winter of 1916, and sold during the summer of 1917 at 7 cents per pound, an average of \$77 per head. The steers purchased during the fall of 1916 were grade Herefords and grade Shorthorns, being sired by pure-bred bulls. The yearling cattle in the fall of 1917 cost \$27 each, and the two-year-old cattle \$41 each. The yearling cattle at the end of the summer of 1918 were worth \$55 each. The cattle were principally steers, although a few heifers were used.

OUTLINE OF THE EXPERIMENTS

The experiments were outlined for the purpose of comparing dry feed with and without cottonseed meal for yearling and two-year-old cattle, and silage with and without cottonseed meal for yearling and two-year-old cattle. Data were kept for one year on each group of steers, and for some of the groups data were kept two years. Individual weights of the cattle on experiment were taken, except for the first year. The outline of the experiments is shown in the following table:

* The wood-hoop silo made of flooring is preferable for most farmers. Write to the Experiment Station, Knoxville, for Wood-hoop Silo Bulletin.

OUTLINE OF EXPERIMENTS

| Year | Age of steers at beginning | Group | Ration |
|---------|----------------------------|-------|---|
| 1914-15 | 2 years | I | Dry feed |
| | | II | 15 lbs. silage; 2 lbs. cottonseed meal |
| | | III | 30 lbs. silage; 1 lb. cottonseed meal |
| 1915-16 | 2 years | I | Dry feed |
| | | II | 15 lbs. silage; 2 lbs. cottonseed meal |
| | | III | 30 lbs. silage; 1 lb. cottonseed meal |
| | | IV | 15 lbs. silage; 1 lb. cottonseed meal; 5 lbs. hay |
| 1916-17 | 3 years | I | Dry feed |
| | | II | 15 lbs. silage; 2 lbs. cottonseed meal |
| | 1 year | III | Dry feed; $\frac{3}{4}$ lb. cottonseed meal |
| | | IV | 10 lbs. silage; $1\frac{1}{2}$ lbs. cottonseed meal |
| | | V | 10 lbs. silage; $\frac{3}{4}$ lb. cottonseed meal; 5 lbs. hay |
| | 2 years | VI | Dry feed |
| | | VII | 10 lbs. silage; $\frac{3}{4}$ lb. cottonseed meal; 5 lbs. hay |
| 1917-18 | 1 year | I | Dry feed; $\frac{3}{4}$ lb. cottonseed meal |
| | | II | 10 lbs. silage; $\frac{3}{4}$ lb. cottonseed meal; 5 lbs. hay |
| | 2 years | III | Dry feed |
| | | IV | 15 lbs. silage; 2 lbs. cottonseed meal |
| | | V | 15 lbs. silage; 1 lb. cottonseed meal; 5 lbs. hay |
| | 3 years | VI | 15 lbs. silage; 1 lb. cottonseed meal; 5 lbs. hay |

In addition to the above winter rations, cattle from each group were allowed the run of the range during the day when the weather was fair. The amounts of feed were necessarily low, for the reason that the problem of the "mountain farmer" is that of getting the largest number of cattle through the winter without loss. As noted before, the object of the experiments was to test the methods in vogue and at the same time test other rations that might give equally as good or better results and that would at the same time make it possible for the farmer and grazer to winter over the maximum number of cattle per acre of cleared land.

DESCRIPTION OF FEEDS USED

Dry feed. The feed that was given to the "dry-feed" groups each winter consisted chiefly of wild hay, a small quantity of corn stover, and sometimes some badly damaged hay of the better kinds. Less than a full feed of these hays and rough feed was given each day, and when the weather was good the cattle were allowed to gather rough dried grasses and other roughages from the range.

Wild hay. A good description of wild hay on the Plateau is that it is composed of grasses that are similar to sedge grass, except that they are finer in texture. The hay is somewhat wiry and hard, especially when well matured. It is mown during the middle of the summer and is usually well-cured, be-

cause at that time hay is easily cured on the Plateau. It generally contains enough waste material to bed any group that is fed heavily upon it. Aside from the grasses just mentioned it may contain some ferns, small brush, and some "nimble will." In the wild hays that have been used in these experiments there has been but little of the "nimble will". When cattle can get other hay they much prefer it to wild hay. It apparently does not contain enough food value to winter calves or short yearlings without the use of grain in addition. Instances have been known where many calves and short yearlings have died, probably from digestive disorders, when fed exclusively upon this hay. It is considered to be about one-half as valuable as average tame hay.

Silage. The silage was made from corn and sorghum, with the sorghum predominating and the corn well eared, but immature, and was put into the silo generally before frost.

Cottonseed meal. The cottonseed meal was 36 per cent protein meal, and usually cost about \$4 per ton more than the same meal in other parts of the State, on account of the high freight rates to the Plateau.

Tame hay. The hays used for the yearlings would classify as tame hays, for they were made of the clovers and tame grasses.

FEEDING AND CARE AND CONDUCT OF THE EXPERIMENTS

Weighing. It is the habit of cattle on the Plateau, after one or two killing frosts in the fall, to come to the barns and stacks, where feed is stored, and as a result the practice is to begin the feeding of cattle at that time. This experiment was made to conform to this practice, and three-day fall weights were taken at that time. Each steer was labeled with a metal tag and individual weights were taken.

Time of weighing. The average time at which the cattle came up for feed in the fall was the last week in November or the first week in December. Three-day weights were taken at this time, and the experiment was begun. Weights of the cattle were again taken the middle of January. The final spring weights were taken at the time when they were very reluctant to come to the barn for their feed. Three-day weights were taken. The time in the spring when the range grass seemed sufficient for the cattle and they failed to come up for feed averaged about April 8. The cattle were weighed in the forenoons.

Amounts of feed. When the cattle were put on feed in the fall, the feeds were weighed for a few days, until it was known what the measures held, and thereafter they were fed like amounts by measure.

General care. The cattle were stabled in pens in the barn during the night, and, when stormy, during the day. Manure was hauled from time to time during the winter as the weather permitted. When an animal was sick it was isolated and given a pound of epsom salts. The cattle obtained water when let out of pen each day. In the fall of each year they were put on full feed immediately after weighing.

DISCUSSION OF RESULTS

The results of each year's experiment are given in Tables 1 to 9.



SORGHUM, A GOOD ROUGH FEED FOR STOCKER CATTLE

TABLE 1—EXPERIMENTS FOR YEAR 1914-15—TWO-YEAR-OLD CATTLE

| | GROUP I | | GROUP II | | GROUP III | |
|-------------------------------|----------|-------|--|-------|---|-------|
| | Dry feed | | 15 lbs. silage
2 lbs. cottonseed meal | | 30 lbs. silage
1 lb. cottonseed meal | |
| No. head..... | 4 | | 8 | | 7 | |
| | Total | Av'ge | Total | Av'ge | Total | Av'ge |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Initial weights, Dec. 7..... | 2287 | 571.8 | 4376 | 547.0 | 3801 | 543.0 |
| Spring wts., Apr. 15,16,17... | 2090 | 522.5 | 4640 | 580.0 | 3836 | 548.0 |
| Winter gain or loss..... | | -49.3 | | +33.0 | | +5.0 |
| Fall weights, Sept. 27..... | 3364 | 841.0 | 6928 | 866.0 | 5955 | 851.4 |
| Summer gain..... | | 318.5 | | 286.0 | | 303.4 |
| Gain for year..... | 1077 | 269.0 | 2552 | 319.0 | 2154 | 308.4 |

TABLE 2—EXPERIMENTS FOR YEAR 1915-16—TWO-YEAR-OLD CATTLE

| | GROUP I | | GROUP II | | GROUP III | | GROUP IV | |
|--------------------------------|----------|-------|--|-------|---|-------|---|-------|
| | Dry feed | | 15 lbs. silage
2 lbs. cottonseed meal | | 30 lbs. silage
1 lb. cottonseed meal | | 15 lbs. silage
1 lb. cottonseed meal
5 lbs. hay | |
| No. head... | 5 | | 5 | | 5 | | 6 | |
| | Total | Av'ge | Total | Av'ge | Total | Av'ge | Total | Av'ge |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Initial wts.,
Dec.14,15,16 | 3029 | 605.8 | 3058 | 611.6 | 3269 | 653.8 | 3867 | 644.7 |
| Spring wts.,
Apr. 10, 11,12 | 2773 | 554.6 | 3189 | 637.1 | 3287 | 657.4 | 3844 | 640.7 |
| Winter gain
or loss..... | | -51.2 | | +25.5 | | +3.6 | | -4.0 |
| Fall wts.,
Sept.9,11,12 | 4305 | 861.0 | 4703 | 940.6 | 4745 | 949.0 | 5656 | 942.7 |
| Summer gain | | 316.4 | | 303.5 | | 291.6 | | 302.0 |
| Gain for year | 1276 | 255.2 | 1645 | 329.0 | 1476 | 295.2 | 1789 | 298.0 |

TABLE 3—EXPERIMENTS FOR YEAR 1916-17—THREE-YEAR-OLD CATTLE

| | GROUP I* | | GROUP II* | |
|---------------------------------------|----------|--------|--|--------|
| | Dry feed | | 15 lbs. silage
2 lbs. cottonseed meal | |
| | 5 | | 5 | |
| No. head..... | 5 | | 5 | |
| | Total | Av'ge | Total | Av'ge |
| | lbs. | lbs. | lbs. | lbs. |
| Initial weights, Nov. 23, 24, 25..... | 4051 | 810.2 | 4354 | 870.8 |
| Spring weights, Apr. 7, 8, 9..... | 3388 | 677.6 | 3886 | 777.2 |
| Winter gain or loss..... | | -132.6 | | -93.6 |
| Fall weights, Aug. 23, 24, 25..... | 5137 | 1027.4 | 5785 | 1157.0 |
| Summer gain..... | | 349.8 | | 378.8 |
| Gain for year..... | 1086 | 217.2 | 1431 | 287.2 |

* These were, respectively, Groups I and II of years 1915-16.

TABLE 4—EXPERIMENTS FOR YEAR 1916-17—YEARLING CATTLE

| | GROUP III | | GROUP IV | | GROUP V | |
|---------------------------------------|-----------------------------------|-------|---|-------|--|-------|
| | Dry feed
¾ lb. cottonseed meal | | 10 lbs. silage
1½ lbs. cottonseed meal | | 10 lbs. silage
¾ lbs. cottonseed meal
5 lbs. hay | |
| | 6 | | 5 | | 6 | |
| No. head..... | 6 | | 5 | | 6 | |
| | Total | Av'ge | Total | Av'ge | Total | Av'ge |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Initial weights, Dec. 11, 12, 13..... | 2074 | 345.7 | 1440 | 288.0 | 1966 | 327.7 |
| Spring weights, Apr. 10, 11, 12..... | 1780 | 296.7 | 1518 | 305.6 | 1937 | 322.8 |
| Winter gain or loss..... | | -49.0 | | +17.6 | | -3.9 |
| Fall weights, Sept. 19, 21, 22.... | 3228 | 539.0 | 2614 | 522.8 | 3427 | 571.2 |
| Summer gain..... | | 241.3 | | 217.2 | | 248.4 |
| Gain for year..... | 1154 | 192.3 | 1174 | 234.8 | 1461 | 244.5 |

TABLE 5—EXPERIMENTS FOR YEAR 1916-17—TWO-YEAR-OLD CATTLE

| | GROUP VI | | GROUP VII | |
|---------------------------------------|----------|-------|--|-------|
| | Dry feed | | 10 lbs. silage
% lbs. cottonseed meal
5 lbs. hay | |
| No. steers..... | 2 | | 4 | |
| | Total | Av'ge | Total | Av'ge |
| | lbs. | lbs. | lbs. | lbs. |
| Initial weights, Dec. 11, 12, 13..... | 1010 | 505.0 | 1963 | 490.8 |
| Spring weights, Apr. 7, 8, 9..... | 902 | 451.0 | 1886 | 471.5 |
| Winter gain or loss..... | | -54.0 | | -19.3 |
| Fall weights, Sept. 19, 21, 22..... | 1451 | 725.5 | 3030 | 757.5 |
| Gain for year..... | 441 | 220.0 | 1067 | 266.6 |

TABLE 6—EXPERIMENTS FOR YEAR 1917-18—YEARLING CATTLE

| | GROUP I | | GROUP II | |
|---------------------------------------|------------------------------------|-------|---|-------|
| | Dry feed
% lbs. cottonseed meal | | 10 lbs. silage
% lb. cottonseed meal
5 lbs. hay | |
| No. head..... | 5 | | 6 | |
| | Total | Av'ge | Total | Av'ge |
| | lbs. | lbs. | lbs. | lbs. |
| Initial weights, Nov. 21, 22, 23..... | 1407 | 281.4 | 1501 | 250.2 |
| Spring weights, Apr. 4, 5, 6..... | 1448 | 289.6 | 1618 | 269.7 |
| Winter gain or loss..... | | +8.2 | | +19.5 |
| Fall weights, Nov. 13, 14..... | 2293 | 458.6 | 2667 | 444.5 |
| Summer gain..... | | 169.0 | | 174.8 |
| Gain for year..... | 886 | 177.2 | 1166 | 194.3 |

TABLE 7—EXPERIMENTS FOR YEAR 1917-18—TWO-YEAR-OLD CATTLE

| | GROUP III | | GROUP IV | | GROUP V | |
|---------------------------------------|-----------|-------|--|-------|---|-------|
| | Dry feed | | 15 lbs. silage
2 lbs. cottonseed meal | | 15 lbs. silage
1 lb. cottonseed meal
5 lbs. hay | |
| No. head..... | 6 | | 5 | | 6 | |
| | Total | Av'ge | Total | Av'ge | Total | Av'ge |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Initial weights, Nov. 21, 22, 23..... | 2952 | 492.0 | 2437 | 487.4 | 3115 | 519.2 |
| Spring weights, Apr. 4, 6, 9..... | 2595 | 432.5 | 2345 | 469.0 | 2912 | 485.2 |
| Winter gain or loss..... | | -59.5 | | -18.4 | | -34.0 |
| Fall weights, Oct. 19, 20, 21.... | 4147 | 691.2 | 3567 | 715.4 | 4325 | 720.8 |
| Summer gain..... | | 258.7 | | 246.4 | | 235.6 |
| Gain for year..... | 1195 | 199.2 | 1130 | 228.0 | 1210 | 201.6 |

TABLE 8—EXPERIMENTS FOR YEAR 1917-18—THREE-YEAR-OLD CATTLE

| | GROUP VI | |
|---------------------------------------|---|-------|
| | 15 lbs. silage
1 lb. cottonseed meal
5 lbs. hay | |
| No. head..... | 6 | |
| | Total | Av'ge |
| | lbs. | lbs. |
| Initial weights, Nov. 21, 22, 23..... | 4226 | 704.3 |
| Spring weights, Apr. 4, 5, 6..... | 3887 | 647.8 |
| Winter gain or loss..... | | -56.5 |
| Fall weights, Apr. 10, 19, 23..... | 5545 | 924.2 |
| Summer gain..... | | 276.4 |
| Gain for year..... | 1319 | 219.9 |

In order to bring the data in the tables into more condensed form, Table 9 has been prepared, which is a summary of 19 groups of cattle, covering a period of four years' work on the Plateau.

TABLE 9—SUMMARY OF FOUR YEARS' WORK—ALL AGES OF CATTLE

| Age of cattle | Dry feed | | 10-15 lbs. silage
1½-2 lbs. cotton-
seed meal | | 25-30 lbs. silage
1 lb. cottonseed
meal | | 10-15 lbs. silage
¾-1 lb. cotton-
seed meal
5 lbs. hay | |
|-------------------|---------------|---------------------|---|---------------------|---|---------------------|---|---------------------|
| | Yrs.
trial | Av. gain
per yr. | Yrs.
trial | Av. gain
per yr. | Yrs.
trial | Av. gain
per yr. | Yrs.
trial | Av. gain
per yr. |
| | | lbs. | | lbs. | | lbs. | | lbs. |
| 1 year | 2 | 184.8 | 1 | 234.5 | | | 2 | 209.4 |
| 2 years | 4 | 235.9 | 3 | 292.0 | 2 | 301.8 | 3 | 255.4 |
| 3 years | 1 | 217.2 | 1 | 287.2 | .. | ..... | .. | ..... |

It will be noted from the results shown in the tables that in every experiment, regardless of the age of the steers, where they received silage during the winter, either in half-ration quantities or in full-ration quantities, with a small quantity of cottonseed meal, they made more gains for the whole year than where fed the ordinary Plateau wintering ration of rough feed.

The cattle that were fed a one-half ration of silage and two pounds of cottonseed meal daily during the winter months made the best gains for the entire year.

Where a small amount of hay, up to 5 pounds daily, was used to replace one pound of the cottonseed meal, the cattle did not do as well for the entire year as when fed 2 pounds of cottonseed meal daily.

As compared with the Plateau "dry-feed" method, the average increase in yearly gains from the half-ration silage and 2 pounds cottonseed meal was, for the yearlings, 49.7 pounds; for the two-year-olds, 55.1 pounds; and for the three-year-olds, 70.0 pounds.

Table 10 gives data on the same cattle, covering a two-year period, for the same method of feeding during the winter months. Three groups were yearlings at the beginning of the two-year period and two groups were two-year-olds.

TABLE 10—EXPERIMENTS COVERING TWO YEARS

| Group | Kind of feed | No. of steers at beginning | Age of steers at beginning | Winter gain or loss | | Summer gain | | Total gain | | Total gain for 2 years |
|-------|---|----------------------------|----------------------------|---------------------|---------------|---------------|---------------|---------------|---------------|------------------------|
| | | | | 1st year | 2nd year | 1st year | 2nd year | 1st year | 2nd year | |
| I | Dry feed..... | 6 | 1 year | lbs.
-49.0 | lbs.
-59.5 | lbs.
241.3 | lbs.
258.7 | lbs.
192.3 | lbs.
199.2 | lbs.
345.5 |
| | | 5 | 2 years | -51.2 | -132.6 | 316.4 | 349.8 | 255.2 | 217.2 | 421.6 |
| II | 10-15 lbs. silage.....
1½-2 lbs. cottonseed meal..... | 5 | 1 year | +17.6 | -18.4 | 217.2 | 246.4 | 234.5 | 228.8 | 427.0 |
| | | 5 | 2 years | +25.5 | -93.6 | 303.5 | 379.8 | 329.0 | 278.2 | 545.4 |
| III | 10-15 lbs. silage.....
¾-1 lb. cottonseed meal.....
5 lbs. hay..... | 6 | 1 year | -3.9 | -34.0 | 248.4 | 235.6 | 244.5 | 201.6 | 393.1 |

Table 10 confirms the single-year trials, in that the cattle receiving a half feed of silage daily, with 2 pounds of cottonseed meal during the winter months, make the greatest gains for the periods covered. The cattle that were a year old at the beginning of the two-year period made a total gain of 427.0 pounds, which was 61.5 pounds greater than the gain made by the cattle that were feed "dry fed" during the winters of the two-year period.

The cattle on one-half ration of silage and two pounds of cottonseed meal that were two years old at the beginning of the two-year period made a total gain of 545.4 pounds, which was 123.8 pounds greater gain than was made by steers of equal age that had been fed "dry feed" during the winter months.

FALL SHRINK OF CATTLE ON THE PLATEAU

During the last three years of the experiments, weights of the steers were obtained the middle of September, and again the last week in November. In this way it was learned that there is a loss in weight during the period before the cattle come to the barns for feed. It would seem therefore that the time for the cattle to come to the barns for feed is too late to begin the regular winter feeding, and that feeding should begin, probably, at about the time of the first killing frost. It would seem that the cattle come to the barns as a last resort.

Table 11 shows the data obtained on fall shrink.

TABLE 11—TABLE SHOWING FALL SHRINK

| Fall period | No.
of
steers | Av'ge Wt.
1st weighing | Av'ge Wt.
2d weighing | Av'ge fall
shrink |
|--------------------------------|---------------------|---------------------------|--------------------------|----------------------|
| | | lbs. | lbs. | lbs. |
| 1916. Sept. 11 to Nov. 24..... | 10 | 900.8 | 840.5 | 60.3 |
| 1917. Sept. 21 to Nov. 22..... | 23 | 597.8 | 553.5 | 44.3 |
| 1918. Sept. 15 to Oct. 20..... | *7 | 688.4 | 700.0 | +11.6 |
| 1918. Oct. 20 to Nov. 13..... | *9 | 670.3 | 651.9 | 18.4 |

*Only three of these steers overlap both periods.

The average fall shrink during the years 1916 and 1917 was 52 pounds for a period of 42 days preceding November 24. During the fall of 1918 the steers continued to gain until October 20, but shrunk in weight from then until November 13. It is probable that the greatest shrink takes place from the second week in October until the first week in December. That being true the winter feeding of Plateau cattle should begin about the second week in November.

RELATION OF WINTER SHRINK TO YEAR'S GAIN

If the groups of cattle on experiment be grouped according to ages and the gains that they made during the winter months, we have the results shown in Table 12.

TABLE 12—RELATION OF WINTER SHRINK TO YEAR'S GAIN WITH YEARLING CATTLE

| Year | No. of head | Winter loss or gain | Summer gain | Total gain for year |
|--------------|-------------|---------------------|-------------|---------------------|
| | | lbs. | lbs. | lbs. |
| 1916-17..... | 6 | -49.0 | 241.3 | 192.3 |
| 1916-17..... | 6 | -3.9 | 248.4 | 244.5 |
| 1917-18..... | 5 | +8.2 | 169.0 | 177.2 |
| 1917-18..... | 6 | +19.5 | 174.8 | 194.3 |
| 1916-17..... | 5 | +17.6 | 217.2 | 234.5 |
| Average..... | | | | 208.7 |

TABLE 13—RELATION OF WINTER SHRINK TO YEAR'S GAIN, WITH TWO-YEAR-OLD CATTLE

| Year | No. of head | Winter loss or gain | Summer gain | Total gain for year |
|--------------|-------------|---------------------|-------------|---------------------|
| | | lbs. | lbs. | lbs. |
| 1917-18..... | 6 | -59.5 | 258.7 | 199.2 |
| 1916-17..... | 2 | -54.0 | 274.5 | 220.0 |
| 1915-16..... | 5 | -51.2 | 316.4 | 255.2 |
| 1914-15..... | 4 | -49.3 | 318.5 | 296.2 |
| 1917-18..... | 6 | -34.0 | 235.6 | 201.6 |
| 1916-17..... | 4 | -19.3 | 286.0 | 266.7 |
| 1917-18..... | 5 | -18.4 | 246.4 | 228.0 |
| 1915-16..... | 6 | - 4.0 | 302.0 | 298.0 |
| 1915-16..... | 5 | +3.6 | 291.6 | 295.2 |
| 1914-15..... | 7 | +5.0 | 303.4 | 308.4 |
| 1915-16..... | 5 | +25.5 | 303.5 | 329.0 |
| 1914-15..... | 8 | +33.0 | 286.0 | 319.0 |
| Average..... | | | | 271.9 |

TABLE 14—RELATION OF WINTER SHRINK TO YEAR'S GAIN WITH THREE-YEAR-OLD CATTLE

| Year | No. of head | Winterloss or gain | Summer gain | Total gain for year |
|--------------|-------------|--------------------|-------------|---------------------|
| | | lbs. | lbs. | lbs. |
| 1916-17..... | 5 | -132.6 | 349.8 | 217.2 |
| 1916-17..... | 5 | -93.6 | 379.8 | 287.2 |
| 1917-18..... | 6 | -56.5 | 276.4 | 219.9 |
| Average..... | | | | 240.1 |

The average gain for the year for yearling cattle on the Plateau was 208.7 pounds; for the two-year-old cattle, 271.9 pounds; and for the three-year-old cattle, 240.1 pounds.

Largest summer gains for each class of cattle were made where there was the greatest winter loss. It was likewise true, however, that the greatest gains for the year were made where the cattle made some gain during the winter months. It would seem that stocker cattle should be so fed during the winter that they make some gain during the winter months. It is likely that a gain of 75 pounds or less would be within the limits of good practice and could be obtained through the use of a little silage and a pound of cottonseed meal. It is quite essential, however, that cattle be so fed during the winter months that they make some gain, be it ever so little, since the manner of wintering influences the total gain for the year. More than that, good wintering of cattle insures good health, and good health means resistance to disease. Steers that are poorly wintered are much more subject to indigestion and disease, and hence the loss is greater.

SILAGE FOR STOCKER CATTLE ON THE PLATEAU

These experiments prove conclusively that cattle on the Plateau wintered on a small amount of silage and a little cottonseed meal will come through the winter in better condition and will make greater gains for the entire year than will cattle that have been roughed through the winter by methods that are most common to the Plateau. This, however, is not the greatest advantage to the Plateau farmer through the use of silage. The great problem of the Plateau farmer is to produce feed enough to winter through the cattle that he can carry on the range during the summer months. The range is unlimited. The number of cattle that can be ranged throughout the summer is dependent upon the number that can be successfully wintered. An average of 6 to 8 tons, or more, of silage per acre can easily be obtained on the Plateau farms. Basing calculations, then, upon these experiments, an acre of silage would winter seven head of two-year-old cattle, while the same acre producing tame hay would winter not more than two head.

A 100-ton silo can be constructed of rough lumber at a money outlay of from \$75 to \$100. Silage will keep in a silo so constructed as well as in a more expensive one. The silo used in these experiments has been built for five years, and appears to be good for five more years, or longer.

Cattle that were wintered on 15 pounds silage and 2 pounds cottonseed meal made from 15 to 32 per cent better gains for the year than those that were wintered by the ordinary Plateau method of using wild hay and other rough feed.

AGRIC. REFERENCE ROOM

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**VARIETIES OF CORN
AND THEIR ADAPTABILITY TO DIFFERENT SOILS**

BY
C. A. MOOERS

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Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

VARIETIES OF CORN AND THEIR ADAPTABILITY TO DIFFERENT SOILS

BY

C. A. MOOERS

INTRODUCTION

Over 3,000,000 acres in Tennessee are planted annually to field corn. The yield per acre varies greatly, depending on both the season and the productivity of the soil, the average for the entire State being nearly $21\frac{1}{2}$ bushels. The seasonal conditions, with rainfall the most important factor, would admit of a much larger average—at a conservative estimate, between two and three times that obtained at present. This means that were the soil productivity and the cultural methods brought up to the point where the yield was limited by the rainfall, an average yield of 40 to 60 bushels per acre would be expected. Since the methods of culture in common use are at least fairly good, increased soil productivity is the prime essential to any large increase in corn production. There is, however, another factor which affects the yield, and that is the producing capacity of the variety grown. Under the same conditions of soil and season one variety may appreciably outyield another, and do this consistently from year to year.

The average annual yield of the best varieties in the Station trials has been found to surpass the most inferior ones by 25 per cent or more. Many popular and widely-grown varieties yield 5 and even 10 per cent less than the leaders. To show the importance of a superior variety, it may be noted that one which surpasses the average by only one bushel per acre would, if grown exclusively, increase the corn production of the State by 3,000,000 bushels. For numerous reasons the exclusive use of a single variety is neither possible nor advisable, but attention may be called to the fact that through the Division of Extension, which includes the

county agents, and through the farm papers and other agencies, the extensive adoption of a variety can now be quickly brought about. The practical importance, therefore, of varietal experiments, including the methods of investigation and the interpretation of the data obtained, is enormous, and the expenditure of large sums of money on further investigation of this and kindred subjects is amply warranted.

VARIETIES COMMONLY GROWN

The number of varieties being grown in the State is large, amounting certainly to scores and even hundreds, if purely local varieties, such as have been developed by cross-breeding and selection on individual farms, be taken into account.

Varieties with white grain but red cob are grown more extensively than all others combined. The number of varieties of this so-called "red-cob" corn is legion, and is due to the rather common practice of starting with a mixture of varieties, which may be much unlike and often includes a "white-cob," from the progeny of which selection is made and continued from year to year according to the inclination of the grower. Neal Paymaster is a typical and recently popular red-cob variety, but the majority of the varieties have only a local reputation, and are known by the names of the originators, or of growers who have maintained the selections. As would be expected, these varieties vary greatly in both length of season and character of grain.

White varieties with white cobs are grown more or less throughout the State. Many are of local development, such as Webb Improved Watson, Huffman, Looney, and Lewis Prolific varieties, differing widely in character and adaptability. Numerous kinds of white corn have been introduced from other states, among them being Hickory King and the prolifics, Albemarle, Cocke, Marlboro, and others, most of which came to Tennessee from either Virginia or North Carolina.

Colored varieties, yellow and red, are grown, but are not generally popular. Some attention, however, has been given to their improvement by breeding and selection, so that those well adapted to various conditions can be obtained.

EXPERIMENTS UNDER VARIOUS CONDITIONS NECESSARY

First and last, the Station has included in experimental trials nearly one hundred varieties, the majority of which either are or have been grown on Tennessee farms. For the past twelve years special attention has been given to the discovery and trial of local varieties of merit. In this connection valuable assistance has been rendered by county agents, who not infrequently call attention to a variety which, though highly valued in a particular neighborhood,

is practically unknown elsewhere. Of course it is only by getting these varieties together and trying them out under the same conditions of planting and season that a fair comparison can be made. If a variety shows superior merit, its trial in different parts of the State and on soils of different degrees of productiveness is necessary in order to show the range of its profitable use. In general a meritorious variety is adapted to a large section of country, and frequently, but by no means always, to soils which differ widely in productivity.

Results obtained from varietal trials conducted in only one place can not be expected to be fully convincing as a guide to a person living elsewhere, especially in another division of the State or where the soil and climatic conditions are materially different. Thanks to the West Tennessee Experiment Station, located at Jackson, and to the appropriation for cooperative experiments in Middle Tennessee, varietal trials have been made possible for the past eleven years in all three divisions of the State, and have been conducted on various types of soil and under a considerable range of soil productivity.

METHODS OF CONDUCTING THE EXPERIMENTS

In every case land as nearly uniform as possible in productivity was selected and the time and method both of planting and cultivation were alike for all varieties. In most instances the trials were made under each of three different rates of planting, such as 6,000, 8,000 and 10,000 plants per acre on the rich bottom land, 4,200, 5,400 and 6,600 plants per acre on the fertile upland of the University Farm at Knoxville, and 3,000, 4,200 and 5,400 plants per acre at the Jackson Station and in much of the Middle Tennessee cooperative work. These rates were accurately obtained for each variety by planting much more seed than would ordinarily be needed and later thinning the plants when small to the number desired. Attention was also given to the order or arrangement of the varieties, so that those of like habit of growth and length of season were planted in a group to themselves, each group being repeated three times, once at each rate of planting. The plots were small, usually only 1/40 acre for a variety, or a total of six 3-foot rows 60.5 feet long.

As a rule, each variety was cut and shocked as soon as the grain was mature, with the stalk and upper leaves still green. In the course of a few weeks field-cured weights were obtained both of the total crop and of the husked ears. The ears were then bagged, taken to the barn, and in the late winter reweighed and shelled, and the weight of the shelled grain for each variety at each rate of planting was carefully noted.

The seed used in the experiments was obtained each year from an approved source, as far as possible, often from the originator of the variety, in some cases from special seed plots at the University Farm, and occasionally from seedmen. One or more varieties were grown continuously as standards of comparison. For this purpose Hickory King was used more than any other. In addition, Albemarle Prolific and, more recently, Neal Paymaster have been utilized. Both are exceptionally high yielders, the latter being unsurpassed. Hickory King makes a good standard, not because of its high-yielding qualities, but because it is a well-known variety of uniform character. As a matter of fact, it has made medium yields on all types of soil, so that a variety which does not yield better can hardly be considered as in the front rank. Seed of Albemarle was obtained during the earlier years of the experiments from Mr. J. N. Meroney, of Dark's Mill, Tennessee. Later, seed from this strain was grown in special areas on the University Farm. Seed of Neal Paymaster was usually obtained from the originator, Mr. W. H. Neal, of Lebanon, Tennessee. Seed of Hickory King has generally been grown on the University Farm.

An important item is the length of time that a variety should be under trial in order to determine its true value. If a variety is of special merit, at least a 5-year trial appears warranted, both in order to overcome errors incident to work of this kind, and to avoid basing conclusions on a chance season or two which might be either especially favorable or unfavorable to a variety.

CLIMATOLOGICAL DATA

Climatological data for representative localities either in or near which varietal experiments were conducted are given in Table 1.

EXPERIMENTS AT THE KNOXVILLE STATION

Experiments with varieties have been conducted at the Knoxville Station for a number of years. In this bulletin attention will be called only to the results obtained since 1905, when the methods outlined for the conduct of the trials were put into operation. Two kinds of soil have been used, rich bottom land described by the Bureau of Soils as Huntington loam, and upland of good quality, known as Cumberland loam.

In the discussion of this and other series attention is paid only to the yields of grain and of total air-dry crop. Data are given in special chapters in regard to length of season and other varietal characteristics.

ON BOTTOM LAND

In the experiments on the rich bottom land yields were obtained from each of three stands, 6,000, 8,000 and 10,000 plants per acre, as

TABLE 1—CLIMATOLOGICAL DATA OF REPRESENTATIVE LOCALITIES WHERE VARIETAL EXPERIMENTS WERE CONDUCTED—FROM RECORDS OF WEATHER BUREAU, U. S. DEPARTMENT OF AGRICULTURE

| Locality | Elevation
Ft. | Average
date of last
killing
frost in
spring | Average
date of
first killing
frost in
fall | Average rainfall (inches) | | | | | | Average mean temperature (°F) | | | | | |
|--|------------------|--|---|---------------------------|------|------|------|------|-------|-------------------------------|------|------|------|------|-------|
| | | | | April | May | June | July | Aug. | Sept. | April | May | June | July | Aug. | Sept. |
| Knoxville
(East Tennessee) | 900 | Apr. 3 | Oct. 28 | 4.64 | 3.70 | 4.17 | 4.21 | 4.00 | 2.81 | 57.4 | 66.5 | 73.4 | 76.2 | 74.7 | 69.4 |
| Crossville (near)
(Cumberland
Plateau) | 1850 | Apr. 24 | Oct. 14 | 5.40 | 4.50 | 4.93 | 5.59 | 5.04 | 3.42 | 56.0 | 62.0 | 70.0 | 72.7 | 71.0 | 64.9 |
| McMinnville
(Highland Rim) | 1038 | Apr. 15 | Oct. 16 | 5.08 | 3.74 | 4.59 | 5.19 | 3.95 | 3.38 | 58.1 | 67.1 | 74.0 | 76.6 | 75.8 | 70.5 |
| Nashville
(Central Basin) | 654 | Apr. 2 | Oct. 26 | 4.36 | 3.50 | 4.37 | 4.35 | 3.47 | 3.68 | 59.1 | 68.8 | 76.3 | 79.4 | 77.8 | 72.9 |
| Jackson
(West Tennessee) | 450 | Apr. 4 | Oct. 30 | 5.47 | 4.07 | 4.36 | 4.38 | 3.51 | 2.67 | 60.6 | 68.9 | 76.8 | 79.4 | 78.8 | 75.0 |
| Union City
(West Tennessee) | 360 | Apr. 9 | Oct. 25 | 4.61 | 4.33 | 3.22 | 3.71 | 3.62 | 3.47 | 59.3 | 69.1 | 76.3 | 79.6 | 78.5 | 73.8 |

TABLE 2—AVERAGE YIELDS OF CORN PER ACRE IN EXPERIMENTS ON RICH BOTTOM LAND, UNIVERSITY FARM

| Variety | Grain Stover | | Remarks |
|---------------------------|--------------|------|--|
| | Bu. | Tons | |
| Albemarle Prolific | 66.2 | 2.80 | 8-year average (1911-15, 1917-19).
All yields averaged. (This was more favorable to Hickory King than otherwise). |
| Hickory King | 57.1 | 2.01 | |
| Neal Paymaster | 66.2 | 2.29 | |
| Albemarle Prolific | 64.8 | 2.82 | 9-year average (1911-15, 1917-20).
All yields averaged. |
| Neal Paymaster | 64.8 | 2.31 | |
| Albemarle Prolific | 67.0 | 2.89 | 5-year average (1910, 1912-15).
All yields averaged. |
| Hickory King | 61.4 | 2.20 | |
| Batt Prolific | 55.5 | 2.39 | |
| Albemarle Prolific | 61.7 | 2.71 | 5-year average (1914, 1915, 1917-19).
All yields averaged. |
| Hickory King | 53.0 | 1.90 | |
| Neal Paymaster | 62.0 | 2.21 | |
| Biggs Seven Ear | 55.5 | 1.95 | |
| Albemarle Prolific | 56.5 | 2.65 | |
| Neal Paymaster | 59.8 | 2.16 | 4-year average (1917-20). Two
highest yields of each year used. |
| Bloody Butcher | 52.5 | 1.82 | |
| Christenberry | 54.7 | 2.42 | |
| Tennessee Gold Mine | 52.5 | 2.18 | |
| Albemarle Prolific | 72.8 | 2.53 | 9-year average (1905-12).
Yields from two best rates of plant-
ing averaged for the period. |
| Hickory King | 66.3 | 2.21 | |
| Boone County White | 64.7 | 1.97 | |
| Reid Yellow Dent | 66.0 | 1.67 | |
| Albemarle Prolific | 57.5 | 2.50 | 3-year average (1917, 1918, 1920).
Two highest yields of each year used. |
| Neal Paymaster | 59.7 | 2.13 | |
| Buford White Dent | 55.0 | 1.87 | |
| Albemarle Prolific | 56.8 | 2.60 | 2-year average (1913, 1914). |
| Hickory King | 52.4 | 1.89 | |
| Neal Paymaster | 62.0 | 2.22 | |
| Chappell | 48.5 | 2.56 | |
| Albemarle Prolific | 69.9 | 2.53 | 11-year average (1905-14).
All yields averaged for Albemarle
and Coker but two best rates each
year for Hickory King. |
| Hickory King | 65.3 | 2.17 | |
| Coker Prolific | 67.2 | 2.72 | |
| Albemarle Prolific | 69.1 | 2.71 | 5-year average (1911, 1913-15, 1918).
Two highest yields of each year
used. |
| Hickory King | 62.4 | 2.11 | |
| Neal Paymaster | 72.7 | 2.36 | |
| Crook White Giant | 66.8 | 2.37 | 4-year average (1913, 1914, 1915,
1917). Two highest yields of each
year used. |
| Albemarle Prolific | 67.6 | 2.87 | |
| Hickory King | 59.2 | 2.11 | |
| Neal Paymaster | 69.0 | 2.34 | |
| Excelsior | 54.5 | 1.99 | 3-year average (1914, 1915, 1917).
Two highest yields of each year used. |
| Albemarle Prolific | 71.4 | 2.89 | |
| Hickory King | 61.1 | 2.11 | |
| Neal Paymaster | 72.9 | 2.32 | 3-year average (1913, 1914, 1918).
Two highest yields of each year used. |
| Hasting Prolific | 58.2 | 2.62 | |
| Albemarle Prolific | 53.9 | 2.35 | |
| Hickory King | 53.0 | 1.69 | 6 crops (1905-07). Two highest
yields of each year used. |
| Neal Paymaster | 61.2 | 2.09 | |
| Heft | 53.2 | 1.40 | |
| Albemarle Prolific | 76.3 | 2.58 | 5-year average (1908-12). Two
highest yields of each year used. |
| Hickory King | 68.2 | 2.28 | |
| Higgs | 76.4 | 2.83 | |
| Albemarle Prolific | 75.4 | 2.65 | 14-year average (1905-19). Yields
from the two best rates of planting
averaged for the period. |
| Hickory King | 68.8 | 2.18 | |
| Hildreth | 73.5 | 2.64 | |
| Kansas Sunflower | 69.7 | 2.06 | |
| Little Willis | 63.9 | 2.52 | |
| Looney | 68.6 | 2.15 | 7-year average (1905-10). Yields
from two best rates of planting
averaged for the period. |
| Albemarle Prolific | 69.4 | 2.66 | |
| Hickory King | 62.2 | 2.27 | |
| Huffman | 66.8 | 3.11 | 7-year average (1905-10). Yields
from two best rates of planting
averaged for the period. |
| Albemarle Prolific | 70.5 | 2.55 | |
| Hickory King | 67.1 | 2.14 | |
| Iowa Silvermine | 52.7 | 1.85 | 7-year average (1905-10). Yields
from two best rates of planting
averaged for the period. |
| Leaming | 58.4 | 1.47 | |

VARIETIES OF CORN

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TABLE 2 (CONCLUDED)

| Variety | Grain | Stover | Remarks |
|--|-------|--------|---|
| | Bu. | Tons | |
| Albemarle Prolific | 54.8 | 2.67 | 4-year average (1913, 1917-19).
All yields averaged. |
| Hickory King | 47.5 | 1.57 | |
| Neal Paymaster | 54.6 | 2.12 | |
| Jarvis Golden Prolific | 49.4 | 1.82 | |
| Albemarle Prolific | 51.1 | 2.18 | 3-year average (1918, 1919, 1921). |
| Hickory King | 46.8 | 1.53 | |
| Neal Paymaster | 55.0 | 1.86 | |
| Jellicorse Twin | 52.9 | 1.76 | |
| Albemarle Prolific | 69.3 | 2.69 | 5-year average (1908-10, 1914, 1915).
Two highest yields of each year used. |
| Hickory King | 65.7 | 2.11 | |
| Legal Tender | 65.7 | 2.39 | |
| Albemarle Prolific | 72.2 | 2.93 | |
| Hickory King | 66.2 | 2.34 | 5-year average (1911, 1912, 1913-15).
Two highest yields of each year used. |
| Lewis Prolific | 64.1 | 2.31 | |
| Albemarle Prolific | 74.2 | 2.62 | |
| Hickory King | 68.1 | 2.19 | |
| McAuley | 61.1 | 1.79 | 4-year average (1908-11). Two highest yields of each year used. |
| Albemarle Prolific | 73.2 | 2.59 | |
| Hickory King | 66.2 | 2.24 | |
| McMackin Gourd Seed | 66.8 | 2.39 | |
| Albemarle Prolific | 66.6 | 2.55 | 9-year average (1905-07, 1913-18). All yields averaged. Two highest yields of each year averaged would give:
Hickory King 61.1 and 2.10
Albemarle 67.2 and 2.60
Marlboro 60.0 and 2.27 |
| Hickory King | 58.5 | 1.99 | |
| Marlboro Prolific | 58.4 | 2.21 | |
| Albemarle Prolific | 68.8 | 3.17 | |
| Hickory King | 61.9 | 2.38 | 2-year average (1913-15).
All yields averaged. |
| Neal Paymaster | 67.6 | 2.63 | |
| Mercer Prolific (No. 181) | 67.7 | 2.92 | |
| Albemarle Prolific | 70.3 | 2.42 | |
| Hickory King | 60.9 | 2.03 | 3-year average (1905, 1907, 1918).
Two highest yields of each year used. |
| Mosby Prolific | 61.1 | 2.62 | |
| Albemarle Prolific | 71.3 | 3.08 | |
| Hickory King | 64.4 | 2.31 | |
| Piedmont White Dent
(No. 182) | 69.9 | 2.05 | 3-year average (1912, 1913, 1915).
All yields averaged. |
| Albemarle Prolific | 78.2 | 3.12 | |
| Hickory King | 64.1 | 2.40 | |
| Neal Paymaster | 74.4 | 2.48 | |
| Red Dent | 63.2 | 2.88 | 2-year average (1915, 1917). Two highest yields of each year used. |
| Albemarle Prolific | 76.7 | 2.47 | |
| Hickory King | 68.1 | 2.18 | |
| Riley Favorite | 59.9 | 1.41 | |
| Albemarle Prolific | 76.7 | 2.54 | 4 crops (1905-07). Two highest yields of each year used. |
| Hickory King | 68.7 | 2.27 | |
| Sanders Improved | 70.2 | 2.57 | |
| Shaw Improved | 75.4 | 3.69 | |
| Albemarle Prolific | 67.0 | 2.96 | 5 crops (1905-07). Two highest yields of each year used. |
| Neal Paymaster | 68.3 | 2.42 | |
| Webb Improved Watson | 58.0 | 2.43 | |
| Albemarle Prolific | 68.7 | 2.63 | |
| Webb Improved Watson | 66.1 | 2.30 | 11-year average (1905-12, 1919, 1920).
Two best rates of planting averaged for the period. |
| Albemarle Prolific | 68.3 | 2.60 | |
| Webb Improved Watson | 62.7 | 2.18 | |
| Albemarle Prolific | 51.7 | 2.63 | |
| Neal Paymaster | 58.8 | 2.26 | 4-year average (1911, 1912, 1919, 1920). All yields averaged. |
| Weekley Improved | 43.0 | 2.10 | |
| Albemarle Prolific | 71.3 | 2.96 | |
| Hickory King | 64.1 | 2.31 | |
| Neal Paymaster | 69.8 | 2.55 | 3-year average (1912-13, 1915).
All yields averaged. |
| Wild Goose | 65.1 | 2.88 | |
| Albemarle Prolific | 50.4 | 2.20 | |
| Hickory King | 47.6 | 1.60 | |
| Neal Paymaster | 56.1 | 1.97 | 2-year average (1918, 1919). |
| Puckett Improved | 46.3 | 2.07 | |
| Albemarle | 79.7 | 2.84 | |
| Hickory King | 67.9 | 2.31 | |
| No. 77 | 67.2 | 2.22 | 4-year average (1905-07, 1913). |
| | | | |
| | | | |
| | | | |

previously described. Owing to the large number of data, and to the fact that most of the varieties have been grown for only a portion of the past fifteen years, some as short a time as two years, detailed yields for each year have been omitted, but the yields for the period under trial have been averaged and are presented in Table 2, where each variety is compared with one or more of the standards mentioned. It may be noted that as a rule the comparison is based on the two highest yields from the three rates of planting of each season, but in some instances the fairest comparison seemed possible only when the yields from all three rates were used, and in a few instances both sets of results are shown. The yields have been high, the average of Albemarle Prolific for fourteen years being nearly 70 bushels per acre.

COMMENTS ON THE RESULTS FROM THE BOTTOMLAND EXPERIMENTS

Inspection of Table 2 shows that of the 42 varieties recorded 14 made grain yields within 5 per cent of Albemarle Prolific. No variety surpassed Albemarle more than a fraction of a bushel, on the average. Of these 14 varieties only the 8 which follow were in trials for 5 or more years:

| Variety | Years |
|----------------------------|-------|
| Neal Paymaster | 9 |
| Higgs Red-cob | 6 |
| Shaw Improved | 5 |
| Hildreth | 5 |
| Crook White Giant | 5 |
| Huffman | 14 |
| Webb Improved Watson | 11 |
| Cocke Prolific | 11 |

Four of these eight—Shaw Improved, Huffman, Higgs, and Hildreth—are late varieties, as late as can be well grown even in the lower section of the State, and make an extra heavy growth of stalk and leaf. The others are medium-late varieties.

Although early-maturing varieties are evidently surpassed by the later varieties on soil of this character, attention may be called to the excellent grain yields of Piedmont White Dent, a medium-early variety, producing only a light yield of stover.

The total weight of air-dry crop is of importance as an index of value for ensilage purposes. The total production of the heaviest yielders is shown in Table 3. Four varieties yielded more total crop than Albemarle. They are Shaw Improved, Huffman, Higgs, and Cocke Prolific. Mosby and Hildreth yielded practically the same as Albemarle. Both Albemarle and Cocke are considered to be especially good ensilage varieties for average conditions. Shaw Improved, however, under rich-land conditions, makes exceptionally high yields.

TABLE 3—TOTAL PRODUCTION PER ACRE OF HEAVIEST YIELDERS IN THE BOTTOM-LAND EXPERIMENTS—YIELDS ON AIR-DRY BASIS

| VARIETY | TONS |
|------------------------|------|
| Albemarle | 5.31 |
| Red Dent | 4.65 |
| Albemarle | 4.39 |
| Mosby | 4.33 |
| Albemarle | 4.23 |
| Christenberry | 3.95 |
| Albemarle | 4.96 |
| Wild Goose | 4.70 |
| Albemarle | 4.76 |
| Little Willis | 4.31 |
| Albemarle | 4.49 |
| Cocke | 4.60 |
| Albemarle | 4.60 |
| Huffman | 4.98 |
| Albemarle | 4.76 |
| Hildreth | 4.70 |
| Albemarle | 4.72 |
| Higgs | 4.97 |
| Albemarle | 4.69 |
| Sanders Improved | 4.54 |
| Shaw Improved | 5.80 |

TABLE 4—AVERAGE YIELDS OF CORN PER ACRE IN UPLAND TRIALS, UNIVERSITY FARM

| Seasons of 1914, 1915 and 1916 | | | Seasons of 1914, 1915, 1916 and 1917 | | |
|--|-------|--------|--------------------------------------|-------|--------|
| Variety | Grain | Stover | Variety | Grain | Stover |
| | Bu. | Tons | | Bu. | Tons |
| Hickory King | 44.9 | 1.44 | Hickory King | 43.9 | 1.40 |
| Neal Paymaster | 50.4 | 1.57 | Neal Paymaster | 51.3 | 1.61 |
| Excelsior | 44.1 | 1.52 | Excelsior | 42.6 | 1.43 |
| Jarvis Golden Prolific | 43.9 | 1.38 | Jarvis Golden Prolific | 44.0 | 1.39 |
| Lewis Prolific | 41.0 | 1.50 | Red Dent | 39.7 | 1.64 |
| Piedmont White Dent
(No. 182) | 46.9 | 1.31 | Station Yellow | 40.2 | 1.84 |
| Red Dent | 41.5 | 1.71 | Wild Goose | 41.7 | 1.85 |
| Station Yellow | 43.0 | 1.83 | | | |
| Wild Goose | 42.2 | 1.75 | | | |
| Yellow Dent | 38.6 | 1.54 | | | |
| Mercer Prolific
(No. 181) | 49.3 | 1.60 | | | |

TABLE 5—AVERAGE YIELDS OF CORN PER ACRE IN EXPERIMENTS ON THE HIGHLAND RIM

| Variety | Grain | Stover | Remarks |
|------------------------------|----------|-----------|---------------------------|
| Hickory King | Bu. 34.8 | Tons 1.14 | 18 series (1912-17). |
| Albemarle Prolific | 38.5 | 1.82 | |
| Neal Paymaster | 44.3 | 1.11 | 14 series (1914-18). |
| Albemarle Prolific | 40.6 | 1.35 | |
| Hickory King | 33.1 | | 5 series (1915-18). |
| Biggs Seven Ear | 42.4 | | |
| Neal Paymaster | 44.3 | | 4 series (1916, 1918). |
| Biggs Seven Ear | 44.4 | | |
| Hickory King | 32.0 | | 2 series (1915, 1918). |
| Boone County White | 37.4 | | |
| Hickory King | 23.7 | 0.93 | 2 series (1908, 1912). |
| Hannah | 18.2 | 1.24 | |
| Hickory King | 36.5 | 1.21 | 2 series (1914, 1915). |
| Heft | 37.3 | 0.69 | |
| Hickory King | 32.6 | 1.19 | 6 series (1908-17). |
| Iowa Silvermine | 29.1 | 0.84 | |
| Neal Paymaster | 48.8 | 1.18 | 2 series (1915, 1917). |
| Iowa Silvermine | 37.4 | 0.99 | |
| Hickory King | 35.1 | 1.15 | 12 series (1916-18). |
| Neal Paymaster | 43.3 | 1.14 | |
| Piedmont White Dent | 37.8 | 1.06 | |
| Jarvis Golden Prolific | 41.6 | 1.11 | |
| Hickory King | 26.5 | | 3 series (1918). |
| Jellicorse Twin | 31.0 | | (Algood, Baxter, Mayland) |
| Neal Paymaster | 42.5 | | 3 series (1918). |
| Jellicorse Twin | 42.8 | | |
| Hickory King | 23.8 | 0.89 | 3 series (1908-12). |
| Leaming | 24.2 | 0.61 | |
| Hickory King | 36.2 | 1.16 | 6 series (1914-18). |
| Neal Paymaster | 43.2 | 1.11 | |
| Lewis Prolific | 38.1 | 1.21 | |
| Hickory King | 34.5 | 1.15 | 9 series (1914-18). |
| Neal Paymaster | 41.5 | 1.11 | |
| Looney | 37.5 | 1.19 | |
| Hickory King | 32.0 | | 2 series (1915, 1916). |
| Mercer Prolific (No. 181) .. | 33.7 | | |
| Hickory King | 32.0 | 1.09 | 2 series (1908). |
| Morrow | 28.0 | 1.08 | |
| Hickory King | 38.4 | 1.24 | 3 series (1917). |
| Mosby Prolific | 46.4 | 1.61 | |
| Neal Paymaster | 46.1 | 1.07 | 3 series (1917, 1918). |
| Mosby Prolific | 46.4 | 1.61 | |
| Hickory King | 38.2 | 1.17 | 10 series (1912-17). |
| Reid Yellow Dent | 37.2 | 0.86 | |
| Neal Paymaster | 48.7 | 1.08 | 6 series (1914-17). |
| Reid Yellow Dent | 39.5 | 0.91 | |
| Hickory King | 25.4 | 0.92 | 2 series (1908). |
| Proffitt | 25.7 | 0.65 | |
| Shepherd | 21.2 | 0.88 | |
| Hickory King | 42.0 | 1.09 | 3 series (1908-12). |
| Webb Improved Watson .. | 40.1 | 1.33 | |
| Hickory King | 27.7 | 0.93 | 2 series (1918). |
| Weekley Improved | 31.0 | 1.02 | |
| Neal Paymaster | 36.0 | | 2 series (1918). |
| Weekley Improved | 31.0 | | |

ON UPLAND

The yields from the recent upland experiments at the Knoxville Station are given in Table 4. Of the 11 varieties tried for the three-year period, Neal Paymaster and Mercer Prolific (181) easily lead the others, with Piedmont White Dent a fairly close third. Red Dent and Wild Goose varieties, sold on the Knoxville market for a number of years, are evidently inferior yielders.

EXPERIMENTS IN MIDDLE TENNESSEE

Experiments with varieties of corn have been carried out in the middle section of the State since 1908, or from the beginning of the Middle Tennessee cooperative work. Various types of soil with different productivities have been used.

ON THE HIGHLAND RIM

Table 5 gives data from trials conducted on Highland Rim soils. In these experiments Biggs Seven Ear tied Neal Paymaster for first place in a total of four series, and Mosby Prolific and Jellicorse Twin in three series. Jarvis Golden Prolific yielded nearly as well in twelve series, which, of course, carries much more weight than can be laid on the results from three or four series. Albemarle Prolific, Weekley Improved, and Looney did better than the average, but were appreciably surpassed by the leaders.

IN THE CENTRAL BASIN

Table 6 gives a two-year average for each of 5 important varieties in a two-year trial at the State Normal School at Murfreesboro. In this series, which is too short for decisive indications, Neal Paymaster was easily first. Albemarle and Jarvis Golden Prolific were practically tied for second place, with Hickory King and Piedmont White Dent ranking nearly together for third place.

TABLE 6—AVERAGE YIELDS OF CORN PER ACRE IN EXPERIMENTS AT THE STATE NORMAL FARM AT MURFREESBORO (SEASONS OF 1916 AND 1917)

| Variety | Grain | Stover |
|------------------------------|-------|--------|
| | Bu. | Tons |
| Albemarle Prolific ----- | 37.7 | 1.39 |
| Hickory King ----- | 35.2 | 1.07 |
| Neal Paymaster ----- | 43.6 | 1.21 |
| Jarvis Golden Prolific ----- | 36.8 | 1.06 |
| Piedmont White Dent ----- | 34.5 | 1.27 |

ON THE CUMBERLAND PLATEAU

On account of the high elevation of the Plateau the season is too short for the satisfactory use of many of the varieties well adapted to other parts of the State. Even Hickory King is considered a

little late. Fortunately, as is shown by the results presented in Table 7, the variety which gave decidedly the highest yields is Piedmont White Dent, which matures readily on the Plateau. Of other varieties, more thoroughly tested, Jarvis Golden Prolific, Biggs Seven Ear, Neal Paymaster, and Hickory King gave the highest average yields, in the order named.

TABLE 7—AVERAGE YIELDS OF CORN PER ACRE IN EXPERIMENTS ON THE CUMBERLAND PLATEAU

| Variety | Grain | Stover | Remarks |
|--|-------|--------|------------------------|
| | Bu. | Tons | |
| Hickory King | 27.7 | 1.28 | 10 series (1907-18). |
| Albemarle Prolific | 23.1 | 1.43 | |
| Hickory King | 27.3 | 1.08 | 3 series (1914-16). |
| Bate Yellow | 23.2 | 0.78 | |
| Hickory King | 25.3 | 1.06 | 6 series (1916-18). |
| Piedmont White Dent | 34.5 | 1.30 | |
| Biggs Seven Ear | 27.2 | 1.23 | |
| Hickory King | 30.2 | 1.27 | 3 series (1914-16). |
| Blake Red Cob | 26.1 | 1.21 | |
| Hickory King | 27.4 | | 1 series (1915). |
| Boone County White | 24.6 | | |
| Hickory King | 24.4 | 1.06 | 6 series (1908-17). |
| Iowa Silvermine | 21.8 | 0.67 | |
| Hickory King | 23.9 | 0.90 | 6 series (1914-18). |
| Jarvis Golden Prolific | 26.0 | 1.01 | |
| Hickory King | 24.1 | | 1 series (1918). |
| Jellicorse Twin | 25.1 | | |
| Hickory King | 30.1 | 1.31 | 10 series (1907-12). |
| Leaming | 27.9 | 1.07 | |
| Hickory King | 28.2 | 0.90 | 4 series (1916-18). |
| Looney | 25.1 | 0.89 | |
| Hickory King | 24.9 | 0.92 | 2 series (1918). |
| Marlboro Prolific | 26.9 | 1.04 | |
| Hickory King | 31.2 | 1.26 | 4 series (1911, 1912). |
| Morrow | 31.4 | 1.33 | |
| Hickory King | 28.1 | 1.09 | 8 series (1912-18). |
| Piedmont White Dent
(No. 182) | 33.1 | 1.26 | |
| Hickory King | 27.6 | 1.18 | 5 series (1916-18). |
| Neal Paymaster | 27.4 | 1.27 | |
| Piedmont White Dent | 36.1 | 1.07 | |
| Hickory King | 20.7 | 1.26 | 2 series (1912). |
| Rains | 23.7 | 1.09 | |
| Hickory King | 26.0 | 1.18 | 5 series (1912-15). |
| Ramsey | 24.4 | 1.05 | |
| Hickory King | 27.4 | 1.33 | 5 series (1907-12). |
| Webb Improved Watson | 18.9 | 1.46 | |
| Hickory King | 24.9 | 0.92 | 2 series (1918). |
| Weekley Improved | 26.8 | 1.08 | |

EXPERIMENTS IN WEST TENNESSEE AT THE JACKSON STATION

Most of the experiments in West Tennessee were conducted at the Jackson Station, where work of this kind has been done for the past ten years. The average yields of the varieties included in these trials are given in Table 8. Of those in trials for two or more years Neal Paymaster and Jarvis Golden Prolific produced more grain than

TABLE 8—AVERAGE YIELDS OF CORN PER ACRE IN TRIALS AT WEST TENNESSEE STATION (JACKSON)

| Variety | Grain | | Remarks |
|---------------------------------|-------|------|---|
| | Bu. | Tons | |
| Neal Paymaster | 50.9 | 1.49 | 2-year average (1918, 1919). |
| Armstrong | 49.1 | 1.46 | |
| Biggs Seven Ear | 42.8 | 1.26 | |
| Albemarle Prolific | 49.4 | 1.99 | 6-year average (1910, 1911, 1914-17). |
| Hickory King | 48.3 | 2.14 | |
| Boone County White | 41.7 | 1.75 | |
| Albemarle Prolific | 40.3 | 1.67 | 5-year average (1911-15). |
| Hickory King | 36.5 | 1.62 | |
| Cocke Prolific | 39.0 | 1.83 | |
| Hawk Red Cob | 38.9 | 1.67 | 4-year average (1918-21). |
| Neal Paymaster | 55.8 | 1.84 | |
| Eaton Improved Baton | 52.7 | 1.91 | |
| Neal Paymaster | 60.7 | 1.85 | 3-year average (1917-19). |
| Goliad | 48.3 | 2.95 | |
| Vardaman Prolific | 57.8 | 2.15 | |
| Albemarle Prolific | 52.4 | 2.04 | 4-year average (1914-17). |
| Hickory King | 47.5 | 2.12 | |
| Neal Paymaster | 56.3 | 1.92 | |
| Hasting Prolific | 48.2 | 2.56 | 2-year average (1914, 1915). |
| Albemarle Prolific | 36.6 | 1.47 | |
| Hickory King | 36.0 | 1.45 | |
| Neal Paymaster | 40.5 | 1.25 | 3-year average (1915, 1917, 1918).
All yields averaged. |
| Heft | 30.0 | 1.13 | |
| Excelsior | 31.5 | 1.35 | |
| Albemarle Prolific | 47.7 | 1.79 | 2-year average (1910, 1911).
All yields averaged. |
| Neal Paymaster | 55.3 | 1.71 | |
| Henry Grady | 46.3 | 1.84 | |
| Albemarle Prolific | 40.6 | 1.78 | 8-year average (1910-17). Two highest yields for each year averaged. |
| Hickory King | 33.9 | 2.15 | |
| Hildreth | 44.4 | 2.68 | |
| Albemarle Prolific | 48.1 | 1.93 | 4-year average (1910, 1913, 1914, 1916). |
| Hickory King | 43.0 | 1.96 | |
| Huffman | 49.1 | 3.21 | |
| Lewis Prolific | 44.6 | 1.89 | 6-year average (1913-18).
All yields averaged. |
| Albemarle Prolific | 45.7 | 1.94 | |
| Hickory King | 39.1 | 1.74 | |
| Iowa Silvermine | 81.1 | 1.03 | 2-year average (1910, 1911). |
| Albemarle Prolific | 44.8 | 1.83 | |
| Neal Paymaster | 48.6 | 1.71 | |
| Jarvis Golden Prolific | 47.4 | 1.61 | 5-year average (1910-14). |
| Albemarle Prolific | 40.6 | 1.78 | |
| Hickory King | 33.9 | 2.15 | |
| Kansas Sunflower | 37.8 | 1.87 | 2-year average (1913, 1916). All yields averaged for Albemarle and Marlboro, but two highest for each year of Hickory King. |
| Albemarle Prolific | 40.7 | 1.70 | |
| Hickory King | 35.2 | 1.68 | |
| Little Willis | 38.5 | 1.46 | 3-year average (1911-13). |
| Looney | 37.4 | 1.44 | |
| Reid Yellow Dent | 36.5 | 0.91 | |
| Albemarle Prolific | 51.3 | 2.21 | 2-year average (1914, 1916). All yields averaged. |
| Hickory King | 45.7 | 1.88 | |
| Marlboro Prolific | 56.0 | 2.16 | |
| Albemarle Prolific | 40.0 | 1.74 | 2-year average (1914, 1916).
All yields averaged. |
| Hickory King | 34.8 | 1.59 | |
| Matthews | 37.4 | 1.77 | |
| Albemarle Prolific | 40.6 | 1.86 | 5-year average (1914-16, 1918-20). |
| Hickory King | 32.1 | 1.70 | |
| Neal Paymaster | 40.4 | 1.73 | |
| Mercer Prolific (No. 181) | 44.7 | 1.98 | 2-year average (1911, 1912). |
| Neal Paymaster | 51.8 | 1.76 | |
| Mosby Prolific | 46.4 | 2.09 | |
| Albemarle Prolific | 37.8 | 1.69 | Overall |
| Hickory King | 33.0 | 1.88 | |
| Overall | 36.5 | 1.53 | |

TABLE 8 (CONCLUDED)

| Variety | Grain | Stover | Remarks |
|-------------------------------------|-------|--------|--|
| | Bu. | Tons | |
| Albemarle Prolific | 44.8 | 1.82 | 5-year average (1912-16). |
| Hickory King | 41.3 | 1.66 | |
| Piedmont White Dent
(No. 182) .. | 40.4 | 1.33 | |
| Albemarle Prolific | 60.6 | 2.33 | 3-year average (1915-17).
Rives a low yielder each year. |
| Hickory King | 56.0 | 2.43 | |
| Neal Paymaster | 67.0 | 2.19 | |
| Rives | 46.0 | 1.83 | |
| Neal Paymaster | 57.0 | 1.69 | 3-year average (1918-20). |
| Reid White Dent | 40.1 | 1.32 | |
| Weekley Improved | 52.9 | 1.72 | |
| Neal Paymaster | 60.7 | 1.85 | |
| St. Charles White | 50.7 | 1.75 | 3-year average (1917-19). |
| Albemarle Prolific | 50.0 | 1.96 | |
| Hickory King | 43.2 | 2.05 | |
| Webb Improved Watson .. | 40.4 | 1.75 | |
| Albemarle Prolific | 46.4 | 1.52 | 5-year average (1910-13, 1917).
All yields averaged. |
| Hickory King | 40.7 | 1.93 | |
| Webb Improved Watson .. | 35.9 | 1.62 | |
| Neal Paymaster | 60.5 | 1.90 | |
| Station Yellow | 56.3 | 2.24 | 5-year average (1915-19). |
| Williamson | 56.6 | 2.34 | |
| Albemarle Prolific | 46.6 | 2.78 | |
| Hickory King | 42.2 | 1.75 | Results from a very thorough trial
made in 1921. These seven varieties
were repeated 12 times in 1/40-acre
plots. |
| Neal Paymaster | 52.0 | 2.30 | |
| Eaton Improved Baton .. | 49.6 | 2.70 | |
| Jarvis Golden Prolific .. | 43.1 | 2.04 | |
| Jellicorse Twin | 53.7 | 2.44 | |
| Piedmont White Dent | 44.7 | 1.73 | |
| Albemarle Prolific | 36.7 | 1.59 | |
| Hickory King | 31.3 | 1.20 | 2-year average (1913, 1914). |
| Neal Paymaster | 37.5 | 1.33 | |
| No. 77 | 28.7 | 0.97 | |

any of the others. Huffman, Albemarle, and similar varieties, such as Cocke and Vardaman, yield well, but less than the two leaders. In a trial of only one season Jellicorse Twin slightly outyielded Neal Paymaster. The result is of interest because of the unusual number of replications—12 for each variety.

The growing season at Jackson is longer than that at Knoxville by some ten days, and even a late variety like Huffman has ample time in which to mature.

AT MARTIN AND PARIS

Varietal trials were conducted for two years at both Martin and Paris, which are near the northern edge of West Tennessee. As

TABLE 9—AVERAGE YIELD OF CORN PER ACRE IN EXPERIMENTS AT PARIS AND MARTIN

| Variety | Grain | Stover | Remarks |
|-------------------------------------|-------|--------|------------------------|
| | Bu. | Tons | |
| Albemarle Prolific | 37.9 | 1.43 | 3 series (1916, 1917). |
| Hickory King | 35.8 | 1.06 | |
| Neal Paymaster | 44.9 | 1.42 | |
| Jarvis Golden Prolific .. | 40.2 | 1.05 | |
| Looney | 33.5 | 1.22 | |
| Piedmont White Dent
(No. 182) .. | 40.4 | 1.15 | |

shown in Table 9, Neal Paymaster outyielded the others, with Jarvis Golden Prolific and Piedmont White Dent tied for second place, followed by Albemarle, Hickory King and Looney.

THE EXPERIMENTAL DATA CONSIDERED AS A WHOLE

In spite of the fact that the varieties were tested under a wide range of soil conditions, both rich and poor, of various physical types, and under such differences as are brought about by changes

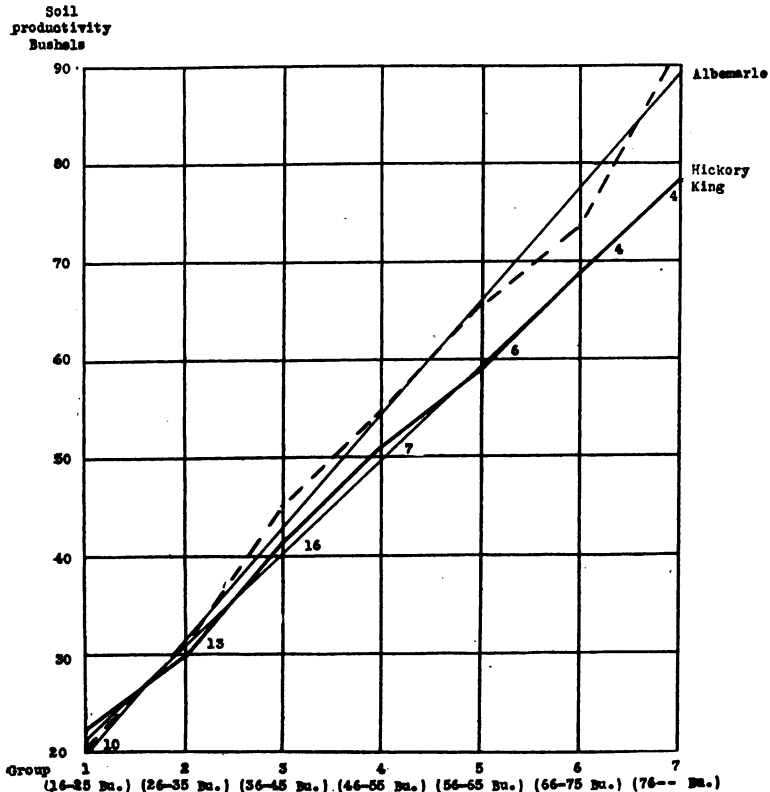


FIG. 1. ALBEMARLE VERSUS HICKORY KING

in altitude, from 400 to 2,000 feet, and differences in longitude up to 350 miles, certain varieties are prominent throughout as high yielders. This is true especially of Neal Paymaster, but also of Albemarle, Piedmont White Dent, Jarvis Golden Prolific and Biggs Seven Ear.

ADAPTABILITY OF A VARIETY TO THE SOIL

To ascertain the relationship, if any, between soil productivity and varietal adaptability, the data for grain production were as-

sembled on the basis of the yield of Hickory King in the following manner:

1. The yields per acre of Hickory King were placed in seven groups, as follows:

- Group 1, yields of 16 to 25 bushels.
- Group 2, yields of 26 to 35 bushels.
- Group 3, yields of 36 to 45 bushels.
- Group 4, yields of 46 to 55 bushels.
- Group 5, yields of 56 to 65 bushels.
- Group 6, yields of 66 to 75 bushels.
- Group 7, yields of 76 bushels and over.

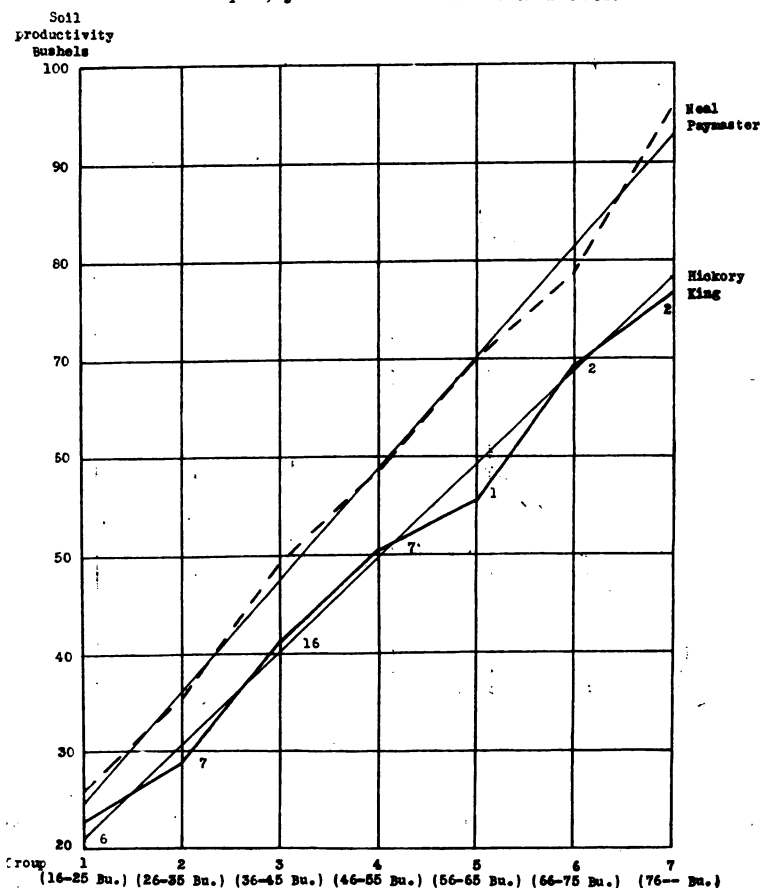


FIG. 2. NEAL PAYMASTER VERSUS HICKORY KING

2. The yields of the variety to be compared were then separated into seven groups, but the group place was determined not by the yield of the variety but by the grouping of Hickory King, the standard of comparison. For example, if Hickory King produced 24 bushels

per acre in a trial in Putman County in 1908, the yield would be placed in Group 1, but the yield of, say, Albemarle for that experiment would be placed in its Group 1 regardless of whether the yield was less or more than 25 bushels per acre. In a similar manner all the groups would be filled out so far as there were direct comparisons between the two varieties. We are now in a position to compare the varieties under different conditions of yield, but without regard to the particular cause of the yield; that is, whether a poor yield, for example, was the result of an unfavorable season on good land or a favorable season on poor land. For a fair and satisfactory comparison, there should be, of course, several yields for each group, for although an average of only two trials may give a valuable indication, especially if adjoining groups are well filled, a large number is much to be desired. Even an average from five or six trials may be materially affected by a single exceptionally high or low yield, so that in judging the comparative worth of any one group the yields of the adjoining groups should be taken into considera-

TABLE 10—RESULTS FROM VARIETY TRIALS OF CORN, SUMMARIZED WITH REGARD TO YIELD OF GRAIN IN BUSHELS PER ACRE—HICKORY KING USED AS THE STANDARD IN THE GROUP PLACEMENT

| GROUP | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|-------------------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| Variety | 16-25 | 26-35 | 36-45 | 46-55 | 56-65 | 66-75 | 76— |
| Hickory King | ¹⁰ 22.3 | ¹³ 30.0 | ¹⁴ 41.4 | ¹⁵ 50.7 | ¹⁶ 58.9 | ¹⁷ 69.2 | ¹⁸ 78.6 |
| Albemarle Prolific | 20.9 | 30.7 | 45.1 | 54.4 | 65.5 | 73.3 | 93.2 |
| Hickory King | ²² 2.8 | ³¹ 0.0 | ³⁹ 9.8 | ⁴⁹ 8 | ⁵⁸ 8.6 | ⁶⁹ 2 | ⁷⁸ 6 |
| Huffman | 21.1 | 27.0 | 40.9 | 48.0 | 57.3 | 68.8 | 90.7 |
| Hickory King | ²² 7 | ²⁸ 7 | ⁴¹ 3 | ⁵⁰ 0 | | | |
| Jarvis Golden Prolific | 23.4 | 34.9 | 47.6 | 53.4 | | | |
| Hickory King | ²² 7 | ²⁸ 7 | ⁴¹ 2 | ⁵⁰ 5 | ⁵⁵ 2 | ⁶⁹ 6 | ⁷⁸ 6 |
| Neal Paymaster | 26.0 | 35.1 | 49.3 | 58.6 | 69.9 | 78.3 | 95.0 |
| Hickory King | ²² 4 | ²⁹ 5 | ⁴⁰ 6 | ⁵⁰ 9 | | ⁷⁴ 5 | |
| Piedmont White Dent
(No. 182) .. | 27.8 | 37.0 | 43.3 | 52.3 | | 79.7 | |
| Hickory King | ²¹ 4 | ³⁰ 4 | ⁴¹ 7 | ⁵⁰ 8 | ⁵⁹ 0 | ⁶⁹ 1 | ⁷⁹ 1 |
| Webb Improved Watson | 19.7 | 26.7 | 39.1 | 49.5 | 62.3 | 63.9 | 83.1 |
| Hickory King | ²² 0 | ³⁰ 5 | ⁴³ 3 | ⁵¹ 9 | ⁵⁹ 4 | ⁶⁹ 1 | ⁷⁹ 1 |
| Boone County White | 16.3 | 33.1 | 43.7 | 45.2 | 54.5 | 70.1 | 79.8 |
| Hickory King | ²³ 0 | ³⁰ 5 | ⁴¹ 2 | ⁵² 9 | ⁵⁸ 2 | ⁶⁹ 7 | ⁷⁹ 1 |
| Reid' Yellow Dent | 21.0 | 31.1 | 40.7 | 45.7 | 53.2 | 68.4 | 78.4 |
| Hickory King | ²¹ 0 | ³⁰ 5 | ⁴¹ 7 | ⁵² 9 | ⁵⁶ 8 | ⁷⁰ 5 | ⁸⁰ 6 |
| Iowa Silvermine | 20.9 | 23.7 | 35.9 | 39.1 | 47.9 | 50.4 | 68.4 |
| Hickory King | ²² 3 | ³⁰ 7 | ³⁹ 8 | ⁴⁹ 4 | ⁵⁷ 1 | ⁶⁸ 6 | ⁸⁰ 6 |
| Leaming | 21.5 | 27.0 | 31.9 | 43.1 | 49.1 | 56.8 | 67.4 |
| Hickory King | ²² 7 | ²⁹ 4 | ⁴⁰ 9 | ⁴⁹ 1 | ⁵⁹ 0 | ⁶⁹ 7 | |
| Looney | 20.8 | 34.4 | 42.6 | 37.3 | 63.2 | 68.2 | |
| Hickory King | ²³ 7 | ²⁹ 1 | ⁴² 9 | ⁵¹ 3 | ⁵⁵ 2 | ⁶⁸ 2 | ⁷⁶ 6 |
| Lewis Prolific | 21.0 | 31.6 | 43.4 | 48.1 | 58.4 | 60.6 | 82.4 |
| Hickory King | ¹⁸ 5 | ²⁸ 2 | ⁴⁰ 9 | ⁴⁸ 3 | ⁵⁵ 2 | | ⁷⁷ 2 |
| Biggs Seven Ear | 20.7 | 31.0 | 47.8 | 54.0 | 59.0 | | 78.1 |
| Hickory King | ²² 0 | ²⁸ 1 | ⁴¹ 8 | ⁵⁰ 0 | ⁵⁵ 2 | | |
| Heft | 15.4 | 28.5 | 41.7 | 50.0 | 54.7 | | |

Note—The number of trials is shown by the superior figure for each group of Hickory King.

tion. Since a relatively large number of trials is necessary in order to get a good average for each of the groups, only a few varieties were found with the requisite data. Even for these the data for some groups are too meager, but the writer considers the comparisons as given in Table 10, and in Figs. 1 to 5, to be of material value.

DISCUSSION OF THE GROUP DATA

The comparisons between Albemarle Prolific and Hickory King are especially instructive because in the foregoing discussions of the experimental results it appears that the former far outclass the latter. From the group data it may be seen that in the trials under conditions of low yield—27 bushels per acre or less—Hickory King somewhat outyielded Albemarle. From, say, 25 to 30 bushels there is only a slight difference between them. Albemarle appears, there-

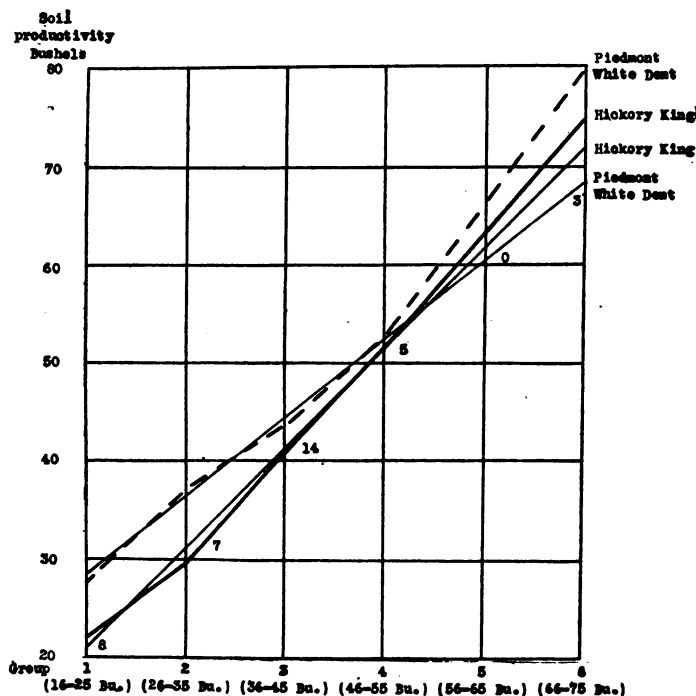


FIG. 3. PIEDMONT WHITE DENT VERSUS HICKORY KING

fore, to be inferior to Hickory King under what may be termed poor-land conditions. On the other hand, the data for Groups 3 to 7 show that under the more favorable conditions Albemarle decisively outyields Hickory King. These conclusions are in harmony with a general but less definite impression gained by the writer in observations of comparative trials of these two varieties.

Another instructive comparison is that between Huffman, long recognized as a rich-land variety, and Hickory King. The group data indicate a decided superiority of Hickory King up to and probably beyond a 35-bushel yield. Above this point there appears to be little choice between these varieties, so far as yield of grain is concerned, until exceptionally favorable conditions are reached, with yields of 75 bushels or more per acre.

The results of trials with Neal Paymaster are of an entirely different order, for it outyields Hickory King under all conditions, from unfavorable to the most favorable. In fact, no other variety has so striking a record. Piedmont White Dent, however, shows a wider margin of superiority under poor-land conditions than Neal Paymaster, but this superiority is not maintained beyond the first two groups. Jarvis Golden Prolific yielded especially well, up to 45 bushels per acre, though the Group 1 results were little better than those from Hickory King.

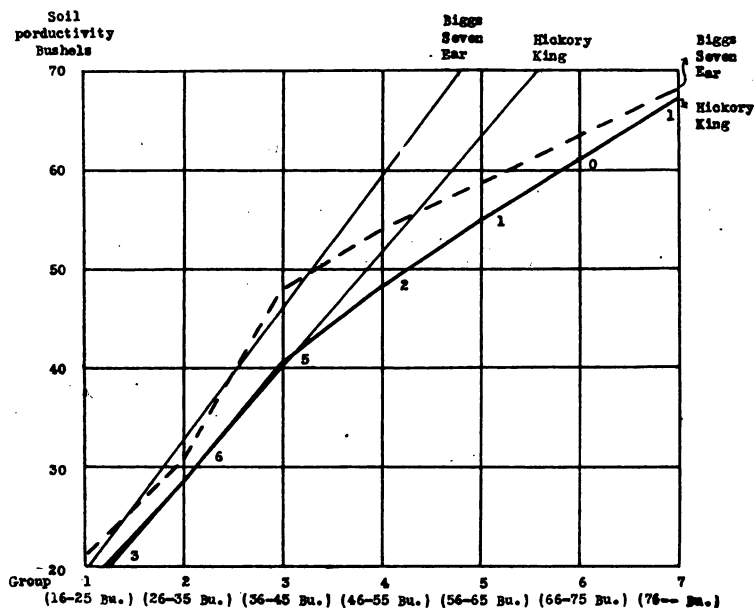


FIG. 4. BIGGS SEVEN EAR VERSUS HICKORY KING

As to other varieties in the group data, Leaming and Iowa Silvermine are surpassed in all groups by Hickory King. Biggs Seven Ear surpasses Hickory King in all groups, and, in fact, is indicated as a high-yielding variety, well suited to average conditions. Boone County White, Reid Yellow Dent, Lewis Prolific, and Heft appear to be nearly or quite on a parity with Hickory King under all conditions of yield. Looney appears to outyield Hickory King on land

producing 25 to 45 bushels per acre, but is not indicated as a good poor-land corn. Webb Improved Watson is indicated as a decidedly inferior yielder under poor-land conditions, but as good as Hickory King or better on 45-bushel land and upward.

The data indicate clearly that a variety may (1) be of inferior value on poor land, but of merit on rich land, as is the case with Albemarle Prolific; (2) do especially well under poor- or medium-land conditions, but not on rich land, as indicated for Piedmont White Dent; (3) like Neal Paymaster, be of high merit on all kinds of soil; and (4) prove inferior to the leaders under all conditions—a variety such as Leaming, for example. In short, adaptability to soil productivity is a very important consideration.

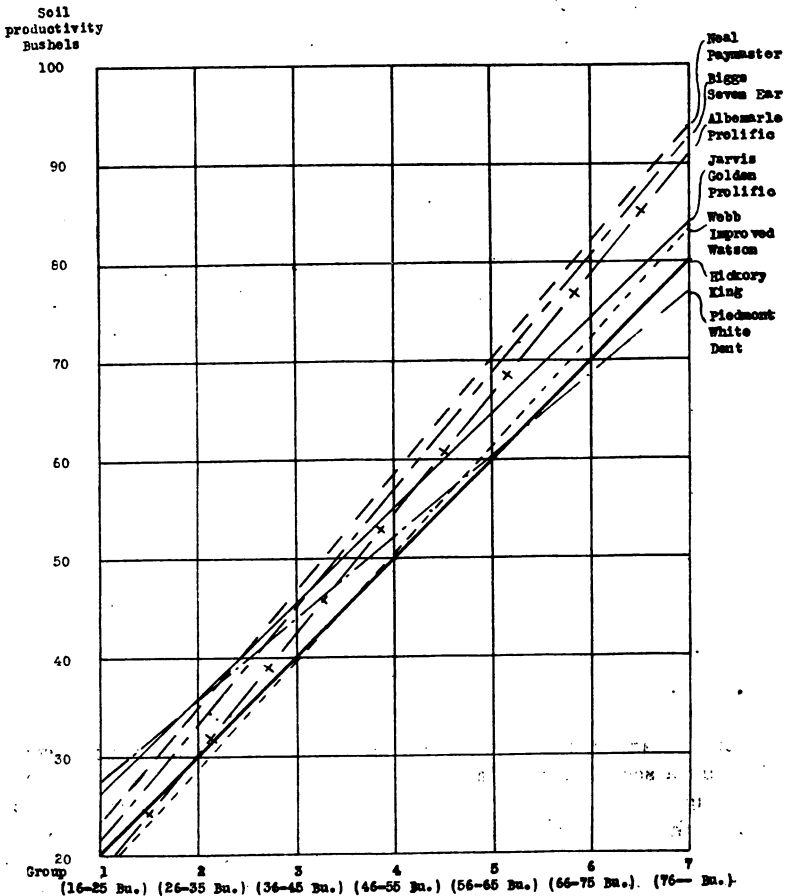


FIG. 5. COMPARATIVE PLACEMENT OF SEVEN IMPORTANT VARIETIES

TABLE 11.—HIGH-YIELDING VARIETIES OF CORN ARRANGED IN GROUPS SHOWING COMPARATIVE ADAPTABILITY TO SOILS OF DIFFERENT DEGREES OF PRODUCTIVENESS AS MEASURED BY THE YIELDS OF HICKORY KING

| Group 1 | Group 2 | Group 3 | Group 4 | Group 5 |
|---|---|---|--|--|
| Very poor land
(16-25 bu.) | Poor land
(26-35 bu.) | Medium land
(36-45 bu.) | Rich land
(46-55 bu.) | Very rich land
(56 bu. and up) |
| <ol style="list-style-type: none"> 1. Piedmont White Dent 2. Jarvis Golden Prolific 3. Neal Paymaster 4. Biggs Seven Ear 5. Hickory King | <ol style="list-style-type: none"> 1. Jarvis Golden Prolific 2. Piedmont White Dent 3. Neal Paymaster 4. Biggs Seven Ear 5. Albemarle Prolific | <ol style="list-style-type: none"> 1. Neal Paymaster 2. Jarvis Golden Prolific 3. Biggs Seven Ear 4. Piedmont White Dent 5. Albemarle Prolific | <ol style="list-style-type: none"> 1. Neal Paymaster 2. Biggs Seven Ear 3. Jarvis Golden Prolific 4. Albemarle Prolific 5. Webb Improved Watson | <ol style="list-style-type: none"> 1. Neal Paymaster 2. Biggs Seven Ear 3. Albemarle Prolific 4. Jarvis Golden Prolific 5. Webb Improved Watson |

VARIETIES INDICATED AS OF SPECIAL VALUE

Fig. 5 shows graphically the relationships of seven of the more prominent varieties as compared with Hickory King. This chart was prepared by first locating each variety in its relation to Hickory King according to the results obtained in the field experiments, as illustrated in Figs. 1 to 4. Next a straight line was drawn to locate the probable relationship in each case had the experimental work been perfect as shown by the light solid lines of Figs. 1 to 4. Finally the relationships were charted as in Fig. 5, which gives in simple and compact form the best information available regarding the comparative values of these varieties on soils differing in productivity.

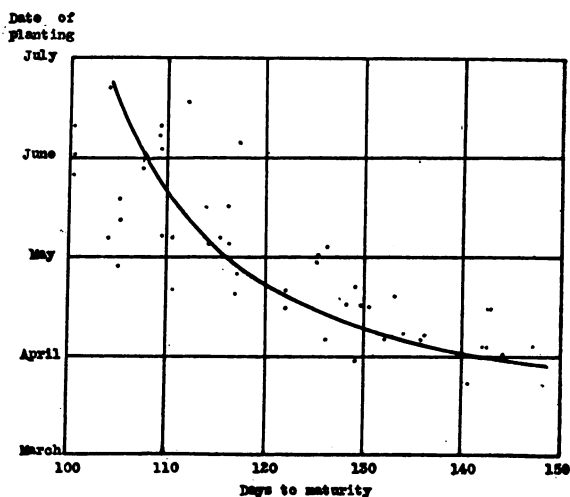


FIG. 6. MATURITY GRAPH OF LEAMING

Table 11 is based on the chart, but special attention is called to the fact that Hickory King is used as the measure of soil productivity, and that had Neal Paymaster been taken the grouping would have been different. Also no special value should be attached to small differences between any two varieties. For example, on soil producing 32 to 40 bushels per acre of Neal Paymaster there is little choice among Neal Paymaster, Jarvis Golden Prolific, and Piedmont White Dent.

In addition to these varieties, which have had fairly long trial, attention may be called to Jellicorse Twin as a very promising variety. The indications are that it will prove nearly or quite the equal of Neal Paymaster as a grain producer.

LENGTH OF SEASON

The number of days from planting to maturity of a given variety of corn varies to some extent with the nature of the season, whether wet or dry, with the productiveness of the soil, and other conditions, but the date of planting is responsible for the greatest

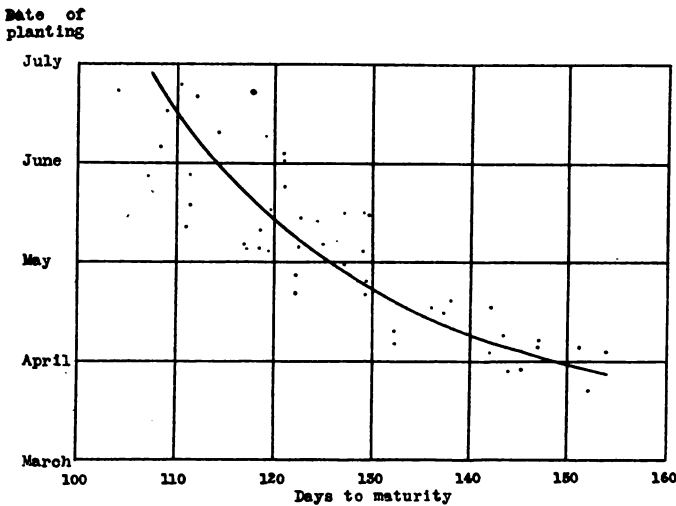


FIG. 7. MATURITY GRAPH OF HICKORY KING

differences. For example, Hickory King when planted the middle of April reaches maturity in about 135 days, but when planted the first of June it reaches maturity in about 111 days. Since most of this shortening takes place prior to blooming, the tendency to bloom during a certain fixed period or length of day is evident. Table 12 shows approximately the number of days between planting and maturity under average Tennessee conditions, the basis for the calculations being April 25 as time of planting. By itself this table gives no indication as to the time required for other dates of planting. This can be approximated, however, by comparison with the data obtained in date-of-planting experiments for each of three varieties, Leaming, an extra early, Hickory King, a medium, and Huffman, a late variety. The data show considerable variations from year to year, and for the present purpose are perhaps best given as in Figs. 6 to 8, in each of which the dots locate the number of days from planting to maturity and the solid line is the average expectancy. Assuming that other varieties with a similar length of season at an April 25 planting would behave in like manner, the date of maturity of any of the varieties can be approximated for any date of planting.

TABLE 12.—VARIETIES OF FIELD CORN GROUPED ACCORDING TO LENGTH OF SEASON FROM PLANTING TO MATURITY—GRAIN HARD, HUSKS DEAD, BUT UPPER LEAVES GREEN. CALCULATIONS BASED ON APRIL 25 AS THE DATE OF PLANTING.

| Extra-Early
(110-117 days) | Early
(118-125 days) | Medium
(126-133 days) | Late
(134-141 days) |
|---|--|---|--|
| Bate Yellow (115)
Blount Prolific (112)
Champion White Pearl (114)
Early Mastodon (113)
Iowa Silvermine (116)
Leaming (115)
Longfellow (111)
100-Day Bristol (112)
Riley Favorite (117)
Thoroughbred (115)
White Cap Dent (117) | Bloody Butcher (124)
Boone Co. White (121)
Hett (122)
Legal Tender (121)
Little Willis (123)
Matthews (125)
Morrow (123)
Piedmont White Dent (120)
Reid Yellow Dent (118)
138 (125)
77 (121) | Albemarle Prolific (127)
Batts Prolific (127)
Biggs Seven Ear (127)
Buford White Dent (130)
Chappell (129)
Christenberry (129)
Cocke Prolific (132)
Crook White Giant (133)
Excelsior (130)
Hawk Red Cob (130)
Hickory King (129)
Jarvis Golden Prolific (129)
Kansas Sunflower (131)
Lewis Prolific (131)
Looney (132)
McAuley (128)
McMackin Gourd Seed (133)
Marlboro (132)
Neal Paymaster (130)
Red Dent (132)
Rives (129)
Rogers White (133)
St. Charles White (129)
Sanders Improved (133)
Tennessee Gold Mine (130)
Tennessee White (128)
Vardaman (132)
Webb Improved Watson (129)
White Majestic (129)
Wild Goose (131) | Big Cob (136)
Goliad
Hasting Prolific (134)
Henry Grady (134)
Higgs (137)
Hildreth (135)
Huffman (138)
Kyker Red Cob (134)
Mercer Prolific (134)
Mexican June (148)
Mosby Prolific (134)
Roseland White (137)
Runner (134)
Shaw Improved (138)
Station Yellow (138)
Tennessee White (137)
Williamson (138) |

THE NUMBER OF EARS PER STALK

The number of ears produced per stalk by any given variety varies with the season, soil productivity, and closeness of stand. The more favorable the season, the richer the soil, and the wider the stand, the greater will be the number. However, it is possible to arrange the varieties in groups which show, at least roughly, their comparative standing in this respect. Table 13 is an attempt to do this from data gathered in the various experimental trials throughout the State.

TABLE 13—VARIETIES OF CORN CLASSIFIED ACCORDING TO NUMBER OF EARS PER STALK—SUMMARY FROM VARIOUS TRIALS

| Class 1
(Very high) | Class 2
(High) | Class 3
(Medium) | Class 4
(Low) |
|--|---|--|--|
| Albemarle Prolific
Batts Prolific
Biggs Seven Ear
Cocke Prolific
Hasting Prolific
Jarvis Golden Prolific
Marlboro Prolific
Mercer Prolific (No. 181)
Puckett Improved
Vardaman Prolific | Goliad
Mosby Prolific
Neal Paymaster
North Carolina Prolific
Pollard Imperial
Sanders Improved
Station Yellow
Williamson | Henry Grady
Hickory King
Kansas Sunflower
Legal Tender
Lewis Prolific
Little Willis
Red Dent
Rives
St. Charles White | Bate Yellow
Bloody Butcher
Boone County White
Buford White Dent
Christenberry
Excelsior
Heft
Higgs
Hildreth
Huffman
Iowa Silvermine
Leaming
Looney
McAuley
McMackin Gourd Seed
Piedmont White Dent
(No. 182)
Reid Yellow Dent
Riley Favorite
Roseland White
Runner
Tennessee Gold Mine
Tennessee White
Tennessee Yellow
White Majestic
Wild Goose |

STALK AND EAR HEIGHTS

The stalk and ear heights of a variety vary with the soil and season. Table 14 was prepared from data obtained in the experiments on rich bottom land at Knoxville and on fertile upland at the Jackson Station. As a rule the heights given in the table are averages of several years' measurements but are not strictly comparable because they do not represent either the same number of years or the same years for more than a few of the varieties listed.

TABLE 14—STALK AND EAR HEIGHTS OF VARIETIES OF CORN—AVERAGES
FROM MEASUREMENTS MADE UNDER RICH-LAND CONDITIONS.
ALSO PER CENT OF GRAIN FOUND IN EAR CORN

| Variety | Bottomland, Knoxville | | Upland, Jackson | | Grain |
|---------------------------|-----------------------|----------|-----------------|----------|----------|
| | Stalk | Ear | Stalk | Ear | |
| | Feet | Feet | Feet | Feet | Per cent |
| Albemarle | 9½ to 11 | 4 to 5 | 8 to 11 | 4 to 6 | 84 |
| Armstrong | | | 9½ to 10 | 5 | 85 |
| Batts Prolific | 9½ to 10 | 4½ to 5½ | | | 85 |
| Biggs Seven Ear | 9 to 10½ | 4 to 5 | 8½ to 9½ | 4 | 85 |
| Bloody Butcher | 7 to 9 | 2½ to 3 | | | 81 |
| Boone County White | 9 to 9½ | 3½ to 4 | 6 to 10½ | 3 to 5½ | 83 |
| Blount Prolific | 7 to 8 | | | | |
| Buford White Dent | 8½ to 9 | 4 | | | 84 |
| Cocke Prolific | 9½ to 10½ | 4 to 5 | | | 83 |
| Crook White Giant | 8½ to 11 | 4 to 5 | | | |
| Crawford White Champion | 11 | 5½ | | | 86 |
| Eaton Improved Baton | | | 8 to 10 | 4 to 5 | 85 |
| Excelsior | 9½ to 10½ | 4½ to 5 | | | 84 |
| Goliad | 11½ | 6½ | 12 to 15 | 6½ to 8 | 82 |
| Hasting Prolific | | | 7 to 11 | 3½ to 6 | 84 |
| Hawk Red Cob | | | | 3½ to 4½ | 55 |
| Heft | 7½ to 8 | 2½ | | | 86 |
| Henry Grady | 10½ | 5½ | 12 | 6 | 84 |
| Hickory King | 8 to 9½ | 3 to 4½ | 7½ to 10 | 3 to 4 | 86 |
| Higgs | 9 | 4½ | | | |
| Hildreth | 9 to 11 | 3½ to 5½ | | | |
| Huffman | 10 to 12 | 4½ to 6 | 7 to 12½ | 4 to 6 | 83 |
| Iowa Silvermine | 7 to 8½ | 3 to 4 | | | 85 |
| Jarvis Golden Prolific | 7 to 8½ | 3 to 3½ | 7½ to 8 | 3 to 3½ | 86 |
| Jellicorse Twin | 9 to 10 | 4 to 5 | 9 to 9½ | 4 to 4½ | 84 |
| Kansas Sunflower | 8 to 10 | 4 to 5½ | | | 85 |
| Leaming | 7 to 9 | 2½ to 3½ | | | 86 |
| Legal Tender | 8½ to 10 | 3 to 4 | | | |
| Lewis Prolific | 9 to 11 | 4½ to 5 | 7 to 11 | 3½ to 5½ | 85 |
| Little Willis | 9½ to 10 | 4½ to 5 | | 3½ to 5 | 85 |
| Longfellow | 8 | 3½ | | | 87 |
| Looney | 9 to 10 | 4 to 4½ | | 3 to 3½ | 84 |
| McAuley | 7½ to 9½ | 4 to 4½ | | | 85 |
| McMackin Gourd Seed | 9 | 4 to 4½ | | | 85 |
| Marlboro Prolific | 9 to 10 | 4 to 5 | 9½ | 4½ to 5 | 85 |
| Matthews | | | | 3½ to 4 | 86 |
| Mercer Prolific (No. 181) | 9 to 10 | 4½ to 5 | 6½ to 9½ | 3½ to 5 | 82 |
| Mexican June | 11 to 14½ | | | | |
| Morrow | 8 | 3½ | | | 82 |
| Mosby Prolific | 9 to 10 | 4½ to 5 | | | |
| Neal Paymaster | 8½ to 10 | 4 to 5 | 8½ to 10 | 4 to 5½ | 85 |
| North Carolina Prolific | | | 9 to 11 | 4 to 6 | 85 |
| Piedmont White Dent | 8 to 9 | 3 to 4½ | 8½ | 3 to 4 | 83 |
| Pollard Imperial | | | 10 | 5 | |
| Puckett Improved | 11 | 6 | | | |
| Red Dent | 9 to 10 | 3½ to 5 | | | |
| Red Hillside | 10 | 5 | | | 85 |
| Reid Yellow Dent | 8 to 9½ | 3 to 3½ | | 3 to 4 | 86 |
| Reid White Dent | | | 8½ to 10 | 3 to 4½ | 85 |
| Riley Favorite | 7½ | 3 | | | 86 |
| Rogers White Dent | 8 | 4 | | | |
| Roseland White | 8½ | 3 | | | 85 |
| Runner | 9½ | 4 | | | |
| St. Charles White | 9 | 4½ | 9 to 10 | 4 to 5 | 85 |
| St. Charles Yellow | | | 10 | 5 | 85 |
| Sanders Improved | 9½ | 4 | | | 86 |
| Shaw Improved | 11 | 5½ | | | |
| Station Yellow | 9 to 10 | 4½ to 5 | 8 to 11 | 4 to 5½ | 84 |
| Tennessee Gold Mine | 9 to 9½ | 4 | | | 85 |
| Tennessee White | 10 to 12 | 7 | | | |
| Thoroughbred | 8 | 2½ | | | 79 |
| Vardaman Prolific | | | 10 | 4½ to 5 | 84 |
| Webb Improved Watson | 9 to 10½ | 4 to 5½ | 11 | 4½ to 6 | 84 |
| Weekley Improved | 9 | 4 | 9 to 10 | 4 to 4½ | 83 |
| White Cap Dent | 7½ | 3 | | | |
| White Majestic | 8½ | 4½ | | | |
| Wild Goose | 10 to 11 | 4½ to 5½ | | | |
| Williamson | 10 | 5 | 10 to 12 | 5 to 6½ | 85 |
| No. 77 | 8 | 3½ | 6 | 3 | 82 |
| No. 138 | 8½ | 3½ | 6 | 3 | 82 |

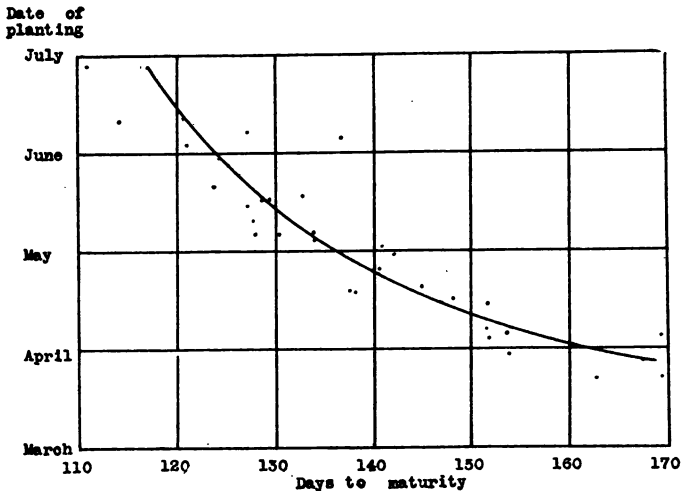


FIG. 8. MATURITY GRAPH OF HUFFMAN

Table 14 also gives the per cent of grain in ear corn as obtained in the experiments. The percentages are probably higher than would be found under usual farm conditions.

REMARKS ON THE VARIETIES

Albemarle. This variety is supposed by the writer to be named from Albemarle County, Virginia. It is a typical white-grain and white-cob prolific, grown extensively on the better class of soils in Virginia; also to some extent throughout the South. Although a high grain producer on fertile land, it is considered to be especially valuable for ensilage purposes.

The length of season required by this variety is medium. The stalk is rather tall and the ears are set rather high on the stalk. The ears are extra sound, of fair length, but slender. The grain is shallow and inclined to be flinty.

After a few seasons of selection the Station was able to get a strain which yielded as well as the original, but which produced a much better type of ear, with deeper grain.

Objections to this variety by farmers are:

1. Ears of small size and set too high on the stalk.
2. Grain too hard.
3. Adapted only to fertile land.

Favorable qualities are:

1. Soundness.
2. High yielding capacity of both grain and stover on fertile land.

Standards suggested for show purposes are:

- Length $9\frac{1}{2}$ inches.
- Circumference* $5\frac{1}{2}$ inches.
- Number of rows 10 or 12.
- Per cent of grain 85.

* Measured about $1\frac{1}{2}$ inches from butt of ear.

Bate Yellow. An early-maturing variety, received from R. O. Bate, Lancing, Morgan County.

Batts. A true prolific resembling Hasting; of North Carolina origin. The ears are small and short, and there is much variation in the size and indentation of the grain. Usual number of rows 12 to 16.

Biggs Seven Ear. About the year 1893 Mr. Noah Biggs, of Scotland Neck, North Carolina, secured a few ears of corn from an attractive field which he saw growing in the northern part of Halifax County, North Carolina. He afterward gave attention to the improvement of the variety, and it became widely known as Biggs Seven Ear. It is highly thought of in North Carolina, and is grown to some extent in various parts of the South.

This variety produces small-sized ears with white cobs and grain. It is a true prolific, having a strong tendency to produce several ears to a stalk, and appears to be well suited to all kinds of soil.

Blake Red Cob. Seed from C. C. Blake, Oakdale, Morgan County. A short-eared, deep-grained variety with large cob. Usual number of rows 18 to 22.

Bloody Butcher. An early-maturing variety, having dark-red, or blood-colored grains. It is grown to a slight extent in various parts of the State.

Blount Prolific. An extra-early prolific. Ears short and unattractive.

Boone County White. A variety that is widely grown both to the north and west of Tennessee, and occasionally in this State. Has good yielding capacity for an early-maturing variety, but lacks soundness.

Buford White Dent. An attractive variety selected and improved by Gil. T. Buford, Pulaski, Giles County.

Chappell. A prolific variety resembling Cocke. Grown in central South Carolina. Received through the U. S. Department of Agriculture. Usual number of rows 10 or 12.

Christenberry. A good selection of red-cob, grown by J. S. Christenberry, Oliver Springs, Roane County.

Cocke. Named for General Cocke, of Bremo farm, in the James River Valley of Virginia. Said to have been grown exclusively in this valley for many years. This is a true prolific and probably the parent of several others of similar character. Apparently a number could be obtained from it by selection. In the Station trials it has yielded practically the same as Albemarle both in grain and forage.

Crawford White Champion. Seed received from T. A. Crawford, Williston, Fayette County.

Crook White Giant. A red-cob variety, received from W. C. Crook, Luray, Henderson County. This variety produces large ears, with large cobs and rather shallow grain, and is best adapted to rich land.

Eaton Improved Baton. A variety grown and selected by P. C. Eaton, Henderson, Chester County, for the past twelve years. It is said to be a leading variety in Prentiss County, Mississippi, where it has been grown for twenty-five or thirty years. The stalks are

tall, but were much less broken down, or lodged, than those of any other variety in the 1921 trials at the Jackson Station.

Excelsior. A white corn of attractive appearance. Seed received from T. W. Wood and Sons, Richmond, Virginia.

Goliad. A giant variety, grown to some extent south of Tennessee, especially for ensilage.

Hannah. A red-cob variety. Seed received from W. H. Smartt, Sparta, White County.

Hasting Prolific. A true prolific characterized by small ears, with small grain of moderate depth. Usual number of rows 12 to 16.

Hawk. A red-cob corn, grown by W R. Hawk, Jackson, Madison County.

Heft. A white variety, noticeable for its short stalk and low-set ears. Seed was received from G. W. Heft, Concord, Tennessee. Mr. Heft writes that he started with a large mixed variety, which set ears too high on the stalk, so that the shocks gave trouble by being blown down. This was about 1883. Since then he obtained the present strain by the continued selection of seed from low-eared stalks. The ears are of medium size, with 14 or 16 rows, and of good soundness. As a grain producer it ranks with Hickory King.

Henry Grady. A variety received from the Alabama Experiment Station.



HICKORY KING

Hickory King. This is a well-known variety, introduced to Southern farmers by A. O. Lee, of Hickory, Virginia. Mr. Lee, in a letter to the writer, states that he began with a single ear given him by a friend in the year 1880, but that he has no further information as to its origin.

The ears are slender but the cob extra small so that the percentage of grain is high. The grain is white, rather hard, large, disc-shaped, and moderately dented. The number of rows is usually 8, but sometimes 10 or 12.

At Knoxville the length of season is considered to be medium.

The vigor and height are good. Under favorable conditions one- and two-eared stalks are almost equally common. The ear is well protected by the husk, which fits rather closely.

Objections to this variety by farmers are:

1. Ears small.
2. Grain hard.
3. Ears somewhat hard to husk.
4. Yield moderate.

Favorable qualities are:

1. Soundness.
2. Good milling quality.
3. Fair adaptability to all kinds of soil.
4. Ease of recognition.

Standards for show purposes are:

- Length $9\frac{1}{2}$ inches.
- Circumference $6\frac{1}{4}$ inches.
- Number of rows 8 or 10.
- Per cent of grain 88.

Higgs. A large, late-maturing variety, of red cob, grown on fertile land in Marshall County.

Hildreth. A large, late-maturing variety of yellow corn. Seed received from the Kansas Experiment Station. Recommended in Kansas for rich land in southeastern part of State. Usual number of rows 18 to 22.



HUFFMAN

Huffman. This variety has been grown in Tennessee for many years. It was obtained by Mr. G. C. Huffman, of Normandy, Tennessee, by long-continued selection from a large-eared, mixed variety, in which white grain and cobs predominated, but which carried some red cobs and blue-colored grain, both of which were finally eliminated. Mr. Huffman began selection in 1857 and for fifty or more years sought to realize his ideals of a show corn of good yielding capacity. It is of interest to note that he limited himself entirely to crib selection. He was highly successful in his underaking, and Huffman corn has won many a grand championship over all competitors at state fairs.

It is a late-maturing, large-stalked variety, with ears set high on the stalk. One ear to the stalk is the rule, though two ears are not uncommon. The ears are large, with deep, shallow-dented grain and small cob. The number of rows is 14 to 18. The variety is well standardized, so that it can be readily distinguished from all others.

Objections to this variety by farmers are:

1. Lateness of maturity and the slow drying out, or curing, of the ears.
2. Adaptation to rich land only.
3. Extra-heavy stalk, with ears too high on the stalk.

Favorable qualities are:

1. High grain yield under favorable conditions.
2. Heavy total yield for ensilage purposes.
3. One large ear to husk instead of two small ones as in a prolific variety.
4. Excellence for milling purposes.

Standards for show purposes are:

Length $10\frac{1}{2}$ inches.

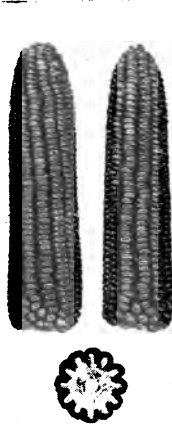
Circumference $7\frac{1}{2}$ inches.

Number of rows 14 to 18.

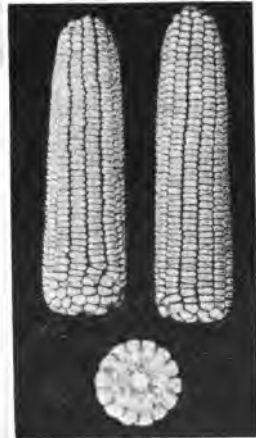
Per cent of grain 88.



NEAL PAYMASTER



JARVIS GOLDEN
PROLIFIC



PIEDMONT WHITE DENT

Iowa Silvermine. An extra-early-maturing variety of white corn, extensively grown in the North. Deficient in soundness when grown under Tennessee conditions.

Jarvis Golden Prolific. This variety was developed by J. M. Jarvis, Winston-Salem, North Carolina. Mr. Jarvis followed much the same method of seed selection as did Mr. Neal for Neal Paymaster; that

is, field selection from stalks which produced two good ears. Probably other points were kept in mind, but the chief consideration was yield.

This variety proved of merit in Station trials in both North Carolina and Tennessee. Up to the present time, however, it has not been widely advertised and is little known to Tennessee farmers. It is of high merit, in particular as it appears to be the best-yielding yellow corn for all kinds of soil that this Station has found.

The stalk is medium in height, appreciably shorter than that of Albemarle Prolific, and the ears are set rather low on the stalk. The ears are rather small, the grain is of moderate depth, only slightly dented, rather hard, and extra sound. The cob is white, an unusual color for a yellow dent corn, but of decided advantage in distinguishing this variety from others.

Objections to this variety by farmers are:

1. Tendency to lodge more than some varieties.
2. Ears rather small.
3. Grain rather hard.

Favorable qualities are:

1. High yield of grain on all soils.
2. Soundness.
3. Easily distinguished grain.

Standards suggested for show purposes are:

- Length 9 inches.
- Circumference $6\frac{1}{4}$ to $6\frac{3}{4}$ inches.
- Number of rows 12 or 14.
- Per cent of grain 87.

Jellicorse Twin. A promising variety of white corn, obtained by continued selection by Reggie Jellicorse, Elmwood, Smith County. Ears are well covered with husks. The grain is sound and of excellent quality. Ears rather small, with 12 to 16 rows.

Kansas Sunflower. A yellow corn, extensively grown in Kansas. Seed received from the Kansas Experiment Station.

Leaming. An extra-early-maturing yellow dent, extensively grown in the North. Deficient in soundness when grown under Tennessee conditions.

Legal Tender. An early-maturing yellow dent, originated in Iowa. Deficient in soundness when grown under Tennessee conditions. Seed received from the Kansas Experiment Station; also from G. H. Northland, Molino, Missouri.

Lewis Prolific. An attractive variety of white corn, bred and selected by E. M. Lewis, McKenzie, Carroll County.

Little Willis. This variety is well known and liked in parts of both Middle and West Tennessee. The length of season required is about the same as for Hickory King. Both the grain and the cob are white. The ears are of good length, slender and tapering, but sound and attractive as a show corn, with straight rows, narrow furrow spaces, and small, medium-dented grain.

For show purposes the ears should be 9 to $9\frac{1}{2}$ inches long and about 6 inches in circumference. The usual number of rows is 16 to 20.

Longfellow. A yellow flint, widely grown in the North.

Looney. This variety was developed by Mr. C. S. Looney, Winchester, Franklin County, Tennessee. It is widely grown and well liked in Franklin County. According to the results of the Station trials, it is best suited to land producing 35 to 40 bushels per acre. It rather closely resembles Webb Improved Watson, the chief difference being that the grain is a little whiter and somewhat wider and thicker than that of Webb. The ears are sound and of attractive appearance.

Standards suggested for show purposes are:

Length 9 to 9½ inches.

Circumference 7 to 7½ inches.

Number of rows 16 to 20.

Per cent of grain 86.

McAuley. A Kansas variety of white dent, a cross between Silvermine and Mortgage Lifter. Seed received from the Kansas Experiment Station.

McMackin Gourd Seed. A deep-grained, large-eared, red-cob variety, of medium season. Seed received from the originator, Dr. J. B. McMackin, Wayland Springs, Lawrence County.

Standards suggested for show purposes are:

Length 9½ to 10 inches.

Circumference 8 to 8½ inches.

Number of rows 18.

Marlboro Prolific. A true prolific of attractive appearance. Said to have been originated by the Excelsior Seed Farm, Cheraw, South Carolina. The usual number of rows is 12 or 14. Seed received from R. T. Malone, Capleville, Shelby County.

Matthews. An attractive white dent, selected by James Matthews, Jackson, Madison County.

Mercer Prolific. A very prolific red-cob corn from Georgia. Ears are small and "nubbiny." Seed received from the U. S. Department of Agriculture as No. 181.

Mexican June. A giant variety, grown to some extent south of Tennessee, especially for a late planting (June). Should not be confused with a small, early-maturing variety of the same name.

Morrow. A red-cob variety, selected for Cumberland Plateau conditions by Jere Morrow, Creston, Cumberland County.

Mosby Prolific. A prolific variety, producing larger ears than Albemarle and Cocke. Extensively grown south of Tennessee, and to some extent in the western portion of this State. Said to have been introduced by J. K. Mosby, Lockhart, Mississippi. Seed received from T. A. Bennett, Vaughan, Mississippi; also from Red Oak Farm, Covington, Tennessee.

Neal Paymaster. A red-cob corn developed by W. H. Neal, of Lebanon, Tennessee. Mr. Neal began some twenty-five years ago with a mixed variety, and has persistently selected his seed corn in the field, using only those plants that produced two good-sized ears to the stalk. He has paid little attention to ear type except, as he says, "to get a deep, well-set grain on a medium-sized cob." White cobs, however, have been bred out, so that more than one white cob in 100 ears indicates a variety other than Neal Paymaster.



NEAL PAYMASTER

Probably no other variety grown in the State gained favor and spread so rapidly as this one. A half dozen years ago it was little known, but now is being widely grown in all parts of the State. Growers like it because it yields well.

It is a medium-season variety, with good, but not oversized, stalk, and ears set at medium height on stalk. With a favorable soil and season, two ears to the stalk are the rule, provided the planting is not too thick. The ears are medium to small in size, tapering, and have 14 or 16 rows, as a rule. The grain is a rather dull-colored white, of good depth, medium dent, and fair soundness.

Objections to this variety by farmers are:

1. Grain not as sound as desired.
2. Somewhat more damaged by stalks being blown down or broken off than some other varieties.
3. Lack of grain or ear characters which would enable it to be readily distinguished from a number of other varieties.

Favorable qualities are:

1. Yield of grain high on all soils.
2. Ears easily husked.
3. Grain not too hard.
4. Stands considerable variation in rate of planting without change in yield.

Standards suggested for show purposes are:

- Length 9 inches.
- Circumference $7\frac{1}{4}$ to $7\frac{3}{4}$ inches.
- Number of rows 14 or 16.
- Per cent of grain 87.

North Carolina Prolific. Seed received from J. A. McNabb and Sons, Somerville, Fayette County.

Piedmont White Dent. The origin and appearance of this variety are described by C. P. Hartley, in Charge of Corn Investigations, U. S. Department of Agriculture, in a circular issued November 14, 1911. It was obtained from crosses between Hickory King and

Boone County White, by the Office of Corn Investigations, and was distributed as "First Generation Cross No. 182"; also as "U. S. Cross No. 182."

It was developed near Washington, D. C., and is grown to a limited extent in parts of Maryland, Virginia, North Carolina, and Tennessee. This is a white-cob and white-grain variety, maturing in about 120 days, when planted in late April. The stalk is short, the ear is slightly tapering, of good size, but only moderately well covered with husk. The grain is of medium depth and dent. The number of rows varies from 14 to 20. One ear to the stalk is the rule.

Both the high yielding capacity of this variety and its short season make it especially well suited to the higher portions of the State, such as the Cumberland Plateau and upper East Tennessee. It is also believed to be well suited to average land throughout the State.

Objections to this variety by farmers are:

1. Only moderate soundness.
2. Ears not well covered with husk.

Favorable qualities are:

1. High yield on land medium to low in productiveness.
2. Short season required.
3. Ease of gathering and husking.

Standards suggested for show purposes are:

- Length 9 inches.
- Circumference $7\frac{1}{4}$ to $7\frac{3}{4}$ inches.
- Number of rows 14 or 16.
- Per cent of grain 85.

Pollard Imperial. Received from T. J. Huddleston, Middleton, Hardeman County.

Puckett Improved. A prolific variety of white corn related to Cocke Prolific. Seed received from A. J. Puckett, Oakman, Georgia.

Rains. A white corn, similar to Ramsey. Well adapted to the Cumberland Plateau. Seed obtained from Henry K. Stockton, Lake, Fentress County.

Ramsey. A well-selected white corn, well suited to the Cumberland Plateau. Seed received from A. C. Ramsey, Algood, Putnam County.

Red Dent. A large-cob, shallow-grain, but sound variety, sold on the Knoxville market. Usual number of rows 14 or 16.

Reid White Dent. A white dent of good appearance, grown by J. V. Reid, Henderson, Chester County.

Reid Yellow Dent. A variety extensively grown in the "corn belt." Occasionally grown in this State. Yields about as well as Hickory King, and is ten days earlier. Deficient in soundness.

Riley Favorite. An extra-early-maturing yellow dent from the "corn belt." Deficient in soundness.

Rives. A small-eared yellow corn. Seed received from J. B. Wade, Dyer, Gibson County.

Roger White Dent. A small-eared prolific from eastern South Carolina. Seed received through the U. S. Department of Agriculture.

Roseland White. A late-maturing Kansas variety. Resembles St. Charles White, but has white cobs.

Runner. A white corn, grown to a limited extent in this State.

St. Charles White. A well-known Missouri "red-cob" corn.

St. Charles Yellow. A Missouri variety of yellow corn.

Sanders Improved. A well-selected white prolific, grown in the South.

Shaw Improved. A tall, late variety of white corn.

Shepherd. A local variety of white corn from the Highland Rim.

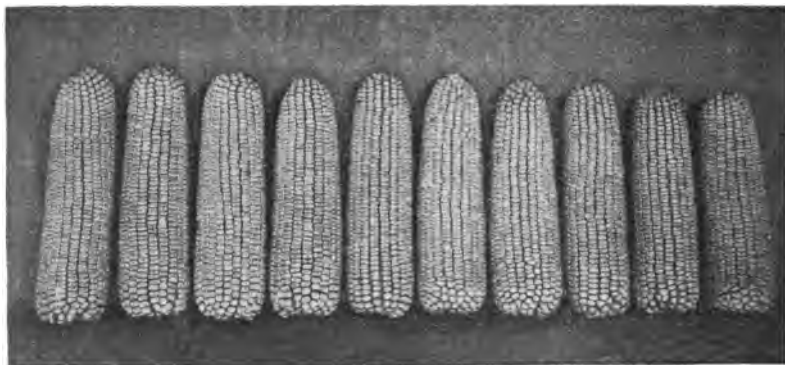
Station Yellow. A flint variety of yellow corn with a white cob, received from the Alabama Experiment Station, where it has been grown for thirty or more years. Recommended as weevil-resistant.

Tennessee Gold Mine. An attractive yellow corn from J. C. Arrington and Sons, Lebanon, Wilson County.

Tennessee White. Seed received from J. W. Scott, Gallatin, Sumner County.

Thoroughbred. A New England variety of white flint.

Vardaman Prolific. A prolific variety, resembling Cocke.



WEBB IMPROVED WATSON

Webb Improved Watson. In 1890 Mr. M. C. Webb of Shelbyville, Bedford County, Tennessee, began to plant Watson corn, a well-known variety in his section, said to have been grown by Squire Watson on Big Flat Creek as early as 1846. By continued crib selection he developed a definite strain known by his name. It has been grown to some extent throughout the State, and has won many premiums at fairs because of its sound and attractive appearance. It is a white-cob, white-grain variety with a length of season about the same as that of Hickory King. The stalk is of medium size. The ears are medium to short in length and much above the average in soundness.

The chief objection to this variety is that it is adapted to rich land only. On land of poor to medium productiveness it is out-yielded by numerous other varieties.

A favorable quality is its soundness, and in this respect it is almost unsurpassed.

Standards for show purposes are:

Length 9 to 9½ inches.

Circumference 7½ to 7¾ inches.

Number of rows 18 to 24.

Per cent of grain 86.

Weekley Improved. A white prolific that has ranked high in varietal trials at the North Carolina Experiment Station, from which the seed was obtained.

White Cap Dent. An extra-early variety of yellow corn, with white cap. Extensively grown in parts of Pennsylvania and elsewhere. Adapted to the highest portions of Tennessee. Seed received from Lancaster County, Pennsylvania; also from Cumberland County, Tennessee.

White Majestic. A rather small-eared white variety of good soundness. Seed obtained from T. W. Wood and Sons, seedmen, Richmond, Virginia.

Wild Goose. A long, chaffy-grained red-cob, grown in the vicinity of Knoxville.

Williamson. A single-eared variety. Seed received from the Pedigreed Seed Company, Hartsville, South Carolina.

No. 77 A variety grown on river bottoms in Southern Ohio. Received as No. 77 from the U. S. Department of Agriculture. Resembles Boone County White.

No. 138. A white variety from Central Tennessee. Seed received as No. 138 from the U. S. Department of Agriculture.

TO THE
ABBOT

677
DEC 22 1927

University of Tennessee
Agricultural Experiment Station
Knoxville

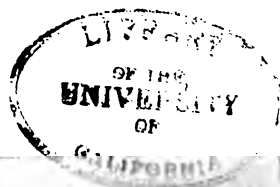
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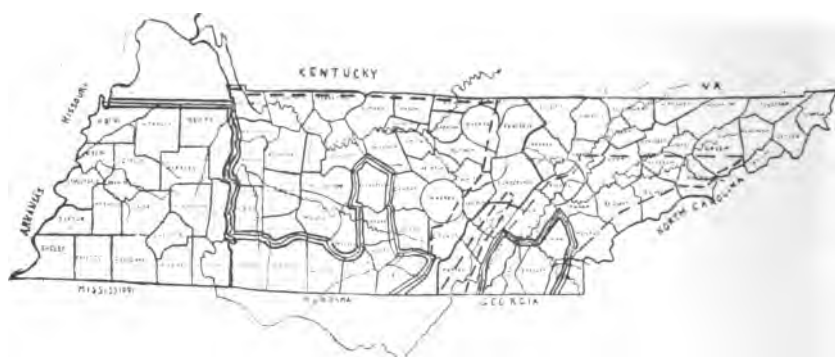
COTTON CULTURE IN TENNESSEE

By

C. A. Mooers and S. A. Robert



A Well-Tended Tennessee Cotton Field



Northern boundaries of counties having 1000 or more acres of
 cotton according to the census of 1919.

Probable limits of profitable production.

COTTON CULTURE IN TENNESSEE

By

C. A. Mooers and S. A. Robert

LIMIT OF PRODUCTION

Cotton has long been an important crop throughout West Tennessee. In years past it has been raised in nearly every county of Middle Tennessee and over a large part of East Tennessee. At the present time it is a staple crop in Middle Tennessee, not only in the counties bordering Alabama, but also in Rutherford County, situated in the center of the State. In East Tennessee it has been little grown outside of McMinn County and those counties which are on the Georgia border.

Due primarily to the invasion by the cotton boll weevil, there has been a marked extension of cotton production both northward and westward. Cotton is now expected to be grown in a number of Tennessee counties where none has been grown within recent years. The probable limits of profitable production in this State are shown in Figure on the opposite page. The areas excluded are the Cumberland Plateau; the Unaka, or Smoky Mountains; and a portion of upper East Tennessee where the altitude reduces both the length of the season and the summer temperature below the requirements of successful culture.

By selecting an "early" soil, planting an early variety, using a suitable fertilizer, and following good cultural methods cotton growers will have an excellent prospect of securing profitable crops over the major portion of the State. It may well be kept in mind, however, that the season is inclined to be short for this crop and that there will be some years in which it is too short and unfavorable for profitable returns.

KIND OF SOIL

Every effort should be made to promote earliness. Therefore, only well-drained and "early" land should be used. Both heavy upland and poorly-drained lowland of any kind should be avoided. Land which the truck grower would select for early vegetables is especially well suited to cotton. Although cotton can be grown successfully on a great variety of soils, it is important that the soil be fertile. Much cotton is grown on poor land, producing less than $\frac{1}{2}$ bale to the acre, but it is then an unprofitable and risky crop. On the other hand, it can be made a highly profitable crop if put on the best land the farm affords.

SOIL PREPARATION AND CROP CULTIVATION

Experimental

Table I gives the yields of seed cotton obtained in a series of experiments continued for seven years at the West Tennessee Experiment Station. The objects of these experiments were to try out various methods of soil preparation and crop cultivation. Experiment No. 4 can be taken as the model, or standard of comparison. In this case the land was plowed, or "flat-broken," early in the spring to a depth of 6 inches. It was afterwards well harrowed and



Rows Firmed with Lap Drag After Seeding

rolled. About ten days before planting, 3-ft. rows were marked off and "bedded"; that is, a low ridge was made over each row. The tops of the rows were harrowed down just before planting. After the cotton was up the cultivation was that commonly recognized as good. As a rule the first working consisted either of cross-harrowing with a spike-tooth harrow, or running a scraper as close to the plants as possible, throwing the dirt away from them. The latter operation is known as "barring off." Hoeing and chopping to a stand followed as soon as possible. The after-tillage depended on the conditions, but the objects were to prevent the growth of weeds and grass, maintain low ridges on which the plants grow and are kept out of the water, and to leave a surface mulch of loose dirt. As a rule only shallow-working implements were used.

Table I.

Yields of seed cotton at the West Tennessee Experiment Station in experiments concerning methods of soil preparation and crop cultivation—Soil a silt loam of good texture, but compacts or “cements” rather hard in dry weather following heavy rains.

| Range | Year | SOIL TREATMENT AND YIELDS PER ACRE | | | | | | | |
|-----------------|------|--|---|--|--|--|--|--|--|
| | | No. 1
Preparation
Weeds
scraped off | No. 2
Turned 6 in.
and “bedded”
Weeds
scraped off | No. 3
No. 3
Preparation
Good
cultivation | No. 4
Turned 6 in.
and “bedded”
Good
cultivation | No. 5
Turned 3 in.
Level planting
Good
cultivation | No. 6
“Bedded” 3 in.
Good
cultivation | No. 7
Turned 6 in.
Level planting
Good
cultivation | No. 8
“Bedded” 6 in.
Good
cultivation |
| 01 | 1916 | lb. 1800 | lb. 2320 | lb. 2120 | lb. 2300 | lb. 2000 | lb. 2020 | lb. 2000 | lb. 1840 |
| 01 | 1917 | 1320 | 1800 | 1600 | 1740 | 1480 | 1740 | 1460 | 1580 |
| 01 | 1918 | 850 | 1070 | 840 | 970 | 980 | 790 | 1060 | 915 |
| 01 | 1919 | 1500 | 1910 | 1890 | 2030 | 2090 | 1770 | 1910 | 2000 |
| 01 | 1920 | 772 | 900 | 1253 | 1222 | 1549 | 1377 | 1660 | 1371 |
| c | 1921 | 1080 | 2800 | 1800 | 2840 | 2920 | 2880 | 2440 | 2680 |
| c | 1922 | 1150 | 1780 | 1360 | 1660 | 1380 | 1640 | 1460 | 1280 |
| Average | | 1210 | 1797 | 1552 | 1823 | 1771 | 1745 | 1713 | 1667 |
| Percentage Rank | | 66 | 99 | 85 | 100 | 97 | 96 | 94 | 91 |

Conclusions Drawn from Experiments

For practical purposes the following conclusions are drawn from the experimental results:

1. The preparation of the land need not be deep. Three-inch breaking with a turn plow gave, within the limits of error for experiments of this kind, the same yield as 6 inch breaking. Turning the land deeper than 6 inches for cotton is indicated as not worth while.

2. With either 3 inch or 6 inch bedding of the rows well in advance of planting time, but without previous plowing or other preparation, the yields were little reduced, on the average only 6½ percent.

3. The so-called "soil mulch," as used in No. 4, gave no appreciable increase in yield over keeping the weeds scraped off without disturbing the surface of the soil, as in No. 2. Keeping the weeds scraped off in this way is not a practiced method of cotton culture, but the results show plainly that cultivation is unprofitable except for the purpose of killing weeds or preventing their growing. That is to cultivate only for the purpose of keeping a soil mulch, which was supposed to conserve the soil moisture, is not worth while.

4. Cotton has the reputation of doing best on a fairly firm seed bed. Even where no soil preparation was given and the weeds were only scraped off without disturbing the hard soil, 66 percent of full crop was obtained. Eighty-five percent of a full crop was obtained in No. 3, where no soil preparation was given, but with as good crop cultivation as for No. 4.

A noticeable result following the growing of cotton continuously without turning the land, as was the case in No. 1, was the increase of diseased plants. The turning of the land holds diseases in check, probably through the death of germs, which were capable of surviving if left on the surface of the ground.

SUGGESTIONS IN REGARD TO SOIL PREPARATION

Implements

The farmer growing cotton for the first time need not purchase any tools additional to those used for corn, potatoes, or the like, unless he plans to put a considerable acreage in cotton, in which case special tools are advisable. Both a disc harrow and a section harrow are highly useful. For bedding up the ridges, the middle breaker, the turn plow, or the disc cultivator may be used. The middle breaker is most commonly used because it does the work rapidly, but the disc cultivator, set properly, does excellent work. For planting, the common type of combination planter, which drills the seed, is all right. The one-row cotton planter with fertilizer distributor is in common use.

Important Considerations

In the preparation of the seed bed and in the cultivation of

cotton certain facts should be kept in mind. First, cotton comes to the best stand and grows off the fastest on a reasonably firm seed bed; second, except in unusual instances, cotton should be planted on a slight ridge; third, a heavy seeding and shallow planting are necessary to insure a stand; fourth, the young cotton plant is quite delicate until growth is well started, but afterwards it will stand considerable neglect.

Methods of Soil Preparation

No set rule can be laid down governing the preparation of the seed bed. The procedure is influenced by the type of soil, the lay of the land, whether level or rolling, the previous crop, seasonal conditions, and the implements at hand. The directions which follow give some of the methods used by experienced growers. One of these methods might be used with any variation necessary to suit a particular condition.

First Method—Cut up all stalks with disc harrow or stalk cutter; plow the land in the fall or winter, leaving the furrow slices on edge. Leave undisturbed until a few days before planting time, then disc if the ground is very rough, lay off the rows, fertilize, and bed up with a middle breaker, a turn plow, or a disc cultivator. Just before planting drag down the rows to the desired height with a section harrow or a plank drag.

Second Method—If cornstalk land is to be used, cut up the stalks, then bed the land in 3-ft. rows with either a middle breaker or a turn plow. If cotton-stalk land be used, after cutting up the stalks throw out the old ridges with a middle breaker or turn plow. Leave until a few days before planting, then disc once, distribute the fertilizer in the water furrow, re-bed the land, drag down the rows, and plant.

Third Method—Cut up stalks; run a bull tongue or a small sweep in the water furrows; ridge by plowing once on each side of the water furrow with a one-horse turn plow. Leave until time to plant. Throw out the balk with a middle breaker or with a turn plow, drag down the beds, and plant. The fertilizer distributor can be used as a substitute for the bull tongue run in the water furrow, the fertilizer being applied at the same time.

Fourth Method—On land inclined to be wet and late in warming up in the spring, throw up high beds, eight to ten feet wide. Let stand until just before planting time, then disc thoroughly to level up the ground, mark off the rows, distribute the fertilizer, bed up the ridges, drag these down, and plant.

Fifth Method—Where it has been impossible to break the land in the fall or winter the ground may be turned a few days before planting time, the rows laid off, the fertilizer applied, and the land re-bedded. The ridges should be well packed in dragging down to give a fairly firm seed bed. A roller or a plank drag well weighted will do this work well.

If the land be bedded up before planting time and allowed to stand for some days, a heavy rain during the interval will firm the soil, and the necessary dragging down prior to planting will kill sprouting weed seeds and make the light mulch which is desired for the seed. On the other hand, should the weather remain dry after bedding, it is well not to wait too long to drag down the ridges, as they will dry out rapidly.

Often after the ground is ready, a hard rain will come before the crop can be planted. The ridges must then be freshened before seeding. This can usually be done satisfactorily with a section harrow run once or twice. A stalk cutter may be run down each row to give the teeth a better hold if needed.

Date of Planting

At the West Tennessee Station the best dates of planting for the last 15 years have been from the last week in April to the middle of May. Table 2 shows the yields obtained in date-of-planting experiments for the past four years. The outstanding result is the marked decline in yields obtained from plantings made in late May and early June. Probably May 1 to 10 is the best time over the major portion of the State.

Table II.

Yields of seed cotton per acre in date-of-planting experiments at the West Tennessee Station.

| YEAR | PLANTING OF | | | |
|-------------|----------------|--------------|--------------|--------------|
| | April 15 to 28 | May 10 to 14 | May 22 to 29 | June 3 to 13 |
| | lb. | lb. | lb. | lb. |
| 1919 ----- | 2,200 | 2,000 | 1,790* | 1,580 |
| 1920 ----- | 1,464 | 1,495* | 1,525 | 828 |
| 1921 ----- | 2,200 | 2,880 | 720 | 480 |
| 1922 ----- | 1,840 | 1,550 | 1,480 | 590 |
| Average --- | 1,926 | 1,981 | 1,379 | 870 |

*Calculated

Width of Row and Distance Between Plants in the Row

The best width of row, according to experimental data from numerous stations, is narrow rather than wide. Three to 3½ foot rows are recommended. Experiments to determine the best distance to leave the plants in the row were made for eight years on a fertile soil at the West Tennessee Station. The results are given in Table III.

Table III.

Effect of distance in row between plants in the yield of cotton.

West Tennessee Station results (3 ft. rows).

Yields of seed cotton per acre.

| YEAR
VARIETY | DISTANCE IN ROW BETWEEN PLANTS AND NUMBER OF PLANTS PER ACRE | | | | | |
|---------------------|--|-----------------------|-----------------------|------------------------|-----------------------|-----------------------|
| | Not Thinned | 3-in. 58080
Plants | 6-in. 29040
Plants | 12-in. 14520
Plants | 18-in. 9680
Plants | 24-in. 7260
Plants |
| | lb. | lb. | lb. | lb. | lb. | lb. |
| 1915 Trice | 1,990 | 2,060 | 1,960 | 2,140 | 1,940 | 1,910 |
| 1916 " | 1,893 | 1,760 | 1,980 | 2,060 | 1,880 | 1,720 |
| 1917 " | 1,107 | 1,250 | 1,140 | 1,190 | 1,160 | 840 |
| 1918 " | 1,120 | 910 | 1,100 | 1,100 | 1,110 | 1,070 |
| 1919 " | 2,306 | 2,200 | 2,220 | 2,240 | 2,140 | 2,390 |
| 1920 " | 878 | 1,215 | 1,490 | 1,645 | 1,735 | 1,700 |
| 1921 Cleve-
land | 2,640 | 2,440 | 2,560 | 2,440 | 2,240 | 1,920 |
| 1922 Ex-
press | 1,640 | 1,520 | 1,640 | 1,840 | 1,760 | 1,490 |
| 8-yr. aver-
age | 1,696 | 1,669 | 1,761 | 1,832 | 1,746 | 1,630 |
| 4 highest
yields | 2,206 | 2,115 | 2,180 | 2,200 | 2,050 | 1,996 |
| 4 lowest
yields | 1,186 | 1,224 | 1,343 | 1,444 | 1,441 | 1,275 |

The data of Table III. indicate that for land of this character the plants should be from 6 inches to 18 inches apart in the row to obtain the highest yield. If the yields from the four best years be averaged together it will be seen that the yields did not vary appreciably whether the cotton were left unthinned or were thinned to one plant every 12 inches. On the other hand, the averages from the four poorest years show that 12 to 18 inch spacing was best. The data obtained by the stations in adjoining states indicate that the season has much to do with the results, but that 12 to 18 inch distances are about right on any soil, from poor to rich. Such a result is not in harmony with the proper spacing of corn, for example, and shows that cotton is far superior to corn in adapting itself to varying stands.

Effect of Thickness of Stand on Earliness

Table IV. shows the effect of thickness of stand on the earliness of the crop in experience continued for six years at the West Tennessee Station. The stand varied from unthinned, which was closer than an average of 3 inches in the row, up to a 24 inch distance in the row. The results show that the difference between plants in

the row affect earliness, though only to a minor extent. The plants in the row thinned to 6 inch and 12 inch distances opened a little earlier than the plants which were either thicker or thinner.

Table IV.

Effect of distance between plants, or "stand," on the earliness of the crop—yields of seed cotton per acre. Trice variety 3-ft. rows. Average results from a six-year trial.

| Date of Picking | DISTANCE BETWEEN PLANTS IN THE ROW AND YIELD | | | | | | | | | | | |
|-----------------|--|------------------|-------------|------------------|-------------|------------------|-------------|------------------|-------------|------------------|-------------|------------------|
| | Unthinned | | 3-in. | | 6-in. | | 12-in. | | 18-in. | | 24-in. | |
| | Lbs. | Percent of Total | Lbs. | Percent of Total | Lbs. | Percent of Total | Lbs. | Percent of Total | Lbs. | Percent of Total | Lbs. | Percent of Total |
| Sept. 1-15 | 380 | 21.8 | 360 | 23.5 | 414 | 24.1 | 414 | 24.0 | 354 | 21.2 | 320 | 19.8 |
| Sept. 16-30 | 324 | 18.6 | 340 | 22.1 | 446 | 26.0 | 414 | 24.0 | 374 | 22.4 | 382 | 23.6 |
| Oct. | 804 | 46.1 | 644 | 41.9 | 654 | 38.1 | 708 | 41.0 | 704 | 42.2 | 674 | 41.7 |
| Nov. | 236 | 13.5 | 192 | 12.5 | 202 | 11.8 | 190 | 11.0 | 238 | 14.2 | 240 | 14.9 |
| Total | 1744 | 100.0 | 1536 | 100.0 | 1716 | 100.0 | 1726 | 100.0 | 1670 | 100.0 | 1616 | 100.0 |

SUGGESTIONS RELATING TO PLANTING AND CULTIVATION

Laying Off the Rows

Cotton rows are not usually laid off except where fertilizer is to be distributed before planting or where one is particular to have the rows uniform in width. The rows may be laid off with the fertilizer distributor when the fertilizer is being put out. A homemade marker with three shovels, which lays off two rows at a time, is excellent. Exact spacing can also be obtained with a two-row planter. In lieu of these implements the old-time bull tongue may be used.

Amount of Seed

Failure to get a good stand of cotton is a common mistake with a beginner. A good stand depends chiefly on three conditions: (1) Shallow planting; (2) an abundance of seed; (3) a well-prepared surface to the rows at planting time. If in walking along the rows after planting one can see uncovered seed here and there, it is a good indication that the planting was about right. Several seed at one place help to break through a soil crust, which would be too strong for a single seed. For these and other reasons, a bushel of seed per acre is advised.

Planting

Since cotton is usually planted on a ridge, a two-row planter cannot often be used. There are two types of cotton planters in

common use. One of these is the old style, inexpensive, Dow-Law Planter, of very simple construction. An abundance of seed can be put out with this planter. The seed are covered with a hollowed-out board drag. This is perhaps the best planter for a careless hand to use. The other style is the combination corn, cotton, and bean planter, with which the cottonseed are placed more nearly in a straight line. The seed are covered with a wheel or roller, which firms the soil about the seed, so that they germinate rapidly. Caution must be exercised to keep from planting too deep with this style of planter. It is easier to cultivate cotton planted with a wheel planter, as it does not pull up so easily when cross-harrowed. Also the plants can be approached closer with a scraper.



Good Preparation and Cultivation

Seeding may be done by hand if no planter is available. Make a shallow trench in the row either with a sweep stock with no point on it or one fitted either with a small bull tongue or a small

sweep. Throw the seed into this trench by hand. With a little practice, from three to six feet can be seeded at one throw. To cover the seed take out the middle teeth of a tooth cultivator and wire a light board to the back teeth. Hold up on the handles while covering if the ground is very soft. The board can be hollowed out in the center if the seed are dragged too much.

Rolling the seed in a thin paste or in clay before planting is not necessary unless there is an excessive amount of lint on the seed. If pressed down in the hopper frequently the seed will usually feed out satisfactorily.

Delinting Seed

✓
✓
✓
Delinted seed are desirable for planting but are not conveniently obtained. Stirring for about 15 minutes in concentrated sulphuric acid, draining off the excess acid and then washing the seed several times with water to remove the remaining acid will result in the seed being not only delinted, but also freed of germs which produce common diseases of cotton, such as leaf spot and boll rot. If small batches are treated at a time one gallon of acid is said to be sufficient for a bushel of seed. Since the acid is destructive to clothing, wood, and iron, care must be exercised. Stone jugs and jars may be used. When not in use, the acid should be kept tightly sealed; otherwise it can absorb a large amount of moisture from the air and may do damage by overflowing the container.

Cultivation

Cultivation should start before the seed have germinated, if a packing rain has fallen after planting. A section harrow with teeth set slanting, run across the rows at an angle, will usually break the crust. It may be necessary to go twice with this implement, in which case it is well to run in an opposite direction the second time.

The big expense in the growing of a cotton crop is usually the hoeing. The adoption of a method of cultivation that reduces this work will effect considerable saving. The object of cultivation is primarily to control the weeds and grass. Generally the implement that does this work most economically and most effectively without undue injury to the plant is the one to use. Seasonal conditions have much to do with the determination of the method of cultivation to be followed.

A large percent of cotton growers, especially on the plantations, practice the scraping of cotton. This is the old-style way. The cotton is "barred off" with a scraper, leaving a narrow strip to be hoed. This is chopped out and the cotton is redirted with a small sweep bridled to keep from covering the plants. Instead of the scraper a one-horse turn plow is often used. Later workings are with larger sweeps, or with a 14-tooth or other one-row cultivator.

Another and more recent method, which is in much favor, is to cross-harrow with the section harrow, with teeth set at an angle, as soon as the plants are well up, followed in a few days by cross-harrowing in the opposite direction. Cross-harrowing can be continued until the plants are about six inches high, if the stand of cotton will permit and if the plants are not too sappy. It is useless,



Cross Harrowing a Good Practice

however, to cultivate in this way if the ground is too packed for the harrow teeth to take hold. In this case, the cotton should be cultivated with either a 14-tooth cultivator, a G-whiz, or some other suitable implement, run just as close to the plants as is possible without loosening their hold on the soil or covering them. These workings should be started as soon as the plants are well up and continued until the limbs begin to overlap in the middles. The heel sweep attached to a one-row cultivator, as shown in the illustration, or a single-heel sweep on a sweep stock, is very good for the late workings if the soil is not too packed. They run under the limbs without doing much injury.

A wet spell may come in midseason and the grass nearly take the crop. In such a case, it may be best to wrap up the grass in the middles with a one-horse plow and later drag down with a cultivator after the grass has been killed. Again when cultivation is delayed by wet weather, the drying out of the ground may be hastened by running a bull tongue or small sweep in the water furrow. This is often done in West Tennessee, even with water standing in the middles here and there, but due to soil differences

this may be unnecessary or even unsafe in other parts of the State.

Generally speaking it is advisable to make the cultivations shallow as the season advances, just as practiced in the cultivation of a corn crop.



Wide Sweeps Used for Shallow Cultivation

FERTILIZERS

The majority of Tennessee soils are in need of phosphorus, nitrogen and lime. Only occasionally—chiefly on certain areas, such as the Barrens of the Highland Rim—has the need of potash been pronounced. The soils used at the West Tennessee Station were found to be well supplied with potash, fairly well supplied with phosphate, but poor in both nitrogen and lime. Wheat, for example, was decidedly benefited by both nitrating and liming, but there was no increase from phosphate even where the trial was continued for several years and all the crops were removed from the land. On the other hand, in a trial lasting seven years, 200 pounds of acid phosphate per acre each year increased the annual yield of seed cotton by 117 pounds. The annual value of the increase was about \$10.00 per acre more than the cost of the phosphate.

Table V. gives the results obtained with nitrate of soda in experiments continued from three to eight years. The last two columns of the table are of special interest because they show the

increase that may be expected from various amounts of nitrate. The average increase from the light application of 40 pounds per acre is 107 pounds of seed cotton. With 120 pounds of nitrate the increase was 219 pounds, only double that obtained from a 40 pound application. A result of this character would be expected, because as the crop increases the moisture supply becomes more and more the factor that limits the size of the crop.

Table V.

Response of cotton to nitrate of soda.

| Nitrate
per acre | Duration
of Trial | YIELDS OF SEED COTTON PER ACRE | | | |
|---------------------|----------------------|--------------------------------|-----------------|--------------------------|---------------------------------|
| | | With Nitrate | Without Nitrate | Increase from
Nitrate | Increase per
cwt. of Nitrate |
| lb. | Years | lb. | lb. | lb. | lb. |
| 120 | 6 | 1670 | 1451 | 219 | 183 |
| 100 | 8 | 1728 | 1518 | 210 | 210 |
| 80 | 7 | 1597 | 1418 | 179 | 224 |
| 40 | 3 | 1363 | 1256 | 107 | 268 |

The result of these experiments indicate that 200 pounds of acid phosphate per acre is advisable, even on soils which are by nature fairly well supplied, though not rich, in phosphorus. For Highland Rim and East Tennessee soils a heavier application is warranted. Nitrate of soda proved high profitable, so that at present prices of cotton (25 to 30 cents per pound) the use of 100 to 150 pounds of nitrate per acre is advised.

Since nitrate of soda is not easily obtainable everywhere, mention should be made of the fact that cottonseed meal is an excellent substitute. Two hundred and fifty pounds of high-grade meal can be used to take the place of 100 pounds of the nitrate. The meal, however, should be mixed with the acid phosphate, so that both can be applied in the row before planting. Also it should be stated that the use of nitrate, cottonseed meal, or other nitrogenous material, is seldom warranted under any of the following conditions:

1. Well-manured land.
2. Where a leguminous crop has been either turned under or grazed off immediately previous to the cotton crop.
3. Where either clover or alfalfa preceded as a hay crop.
4. Where the soil is naturally well supplied with nitrogen, as indicated by a heavy growth of stalk and leaf.

Under any of the foregoing conditions the use of acid phosphate may be highly advisable.

If potash is desired 25 pounds per acre of muriate of potash, or its equivalent of other potash salt, is recommended. It should be mixed with the acid phosphate.

Of the commercial mixtures the truck-growers 10-4-4 is excellent for cotton and is preferable to low-grade mixtures.

Suggestions Relating to the Application of Fertilizer

There are cheap one-row fertilizer distributors on the market that are satisfactory for this purpose. Fertilizers can, of course, be applied by hand. A still day is best for this work. A good plan is to take a stout sack, cut a hole in both sides near the mouth, large enough for a man's head to go through; slip the head through this hole, letting the sack hang down in front; cut away a considerable portion of the front side of the sack, but leave room for 25 to 50 pounds of fertilizer. By walking between two rows, the operator can fertilize a row with each hand. With a combination fertilizer distributor and planter, the phosphate can be applied, at the time of planting and at a considerable saving in labor. Nitrate of soda is applied by hand as a surface dressing in a strip about two feet wide over the row when the plants are small. A good time is immediately after the chopping to a stand.

LIME

Most soils in this State are deficient in lime. This deficiency is more clearly evident with some crops than with others. Cotton must be placed among those crops that do not have a high lime requirement. At the same time it may respond profitably to liming.

In Table VI. are given the results obtained in the course of fifteen years in experiments at the West Tennessee Station. These experiments were conducted with two different crop rotations on each of two distinct types of soil, one a grey-colored, silty, "crawfishy" soil, and the other a brownish silt loam of naturally good quality. The two year rotation was oats followed by cowpeas the same year, cotton, corn and cowpeas. The five year rotation was cowpeas, wheat, clover and grass, cotton, corn.

Table VI.

Effects of liming on cotton—From experiments continued for fifteen years on two types of soil at the West Tennessee Station.

| 3-Year Rotation of Oats—Cowpeas, Cotton,
Corn and Cowpeas | | | | 5-Year Rotation of Cowpeas, Wheat, Clover
and Grass, Cotton, Corn | | | |
|--|---------------------------------------|--|------------|--|---------------------------------------|--|------------|
| Kind of Soil | Number of
Cotton
crops
grown | Average Annual
Yield of Seed
Cotton per Acre | | Kind of Soil | Number of
Cotton
crops
grown | Average Annual
Yield of Seed
Cotton per Acre | |
| | | Limed | Unlimed | | | Limed | Unlimed |
| Grey, silty,
"crawfishy" | 5 | lb.
944 | lb.
968 | Grey, silty,
"crawfishy" | 3 | lb.
1044 | lb.
884 |
| Brownish
silt loam | 5 | 1622 | 1532 | Brownish
silt loam | 3 | 1501 | 1433 |

In the periods mentioned there were harvested, in the case of the three year rotation, five crops of cotton, and in the five year rotation, three crops of cotton. The table shows that in three of the four series liming was profitable. In the three year rotation on the grey-colored soil the unlimed plots yielded somewhat more than the limed. There is a reasonable possibility that the limed section of this series was more fertile than the unlimed. Probably the averages from the two series on each soil type will give the most reliable data from which to draw conclusions. For the grey soil these averages are 994 pounds of seed cotton per acre where limed and 926 pounds where unlimed. For the brownish soil these averages are 1562 pounds of seed cotton per acre where limed and 1483 pounds where unlimed. Although the differences attributed to liming were not great, the conclusion seems to be warranted that the liming was profitable for cotton. For the other crops it proved profitable, in particular for the cowpeas and the clover and grass. In the case of the brownish soil, clover was obtained only on the limed section.

VARIETIES

A Single Variety for the Community Gin

The advantage arising from the growing of a single good variety in a community are worthy of consideration. In the first place, the seed can more easily be kept pure—a troublesome matter where numerous varieties are brought to the same gin. With pure seed either a high yielding and easily picked variety, such as Mexican Big Boll, or a variety producing superior lint, such as Express, can be maintained. A community with a reputation for quality cotton gets the highest market prices, for buyers of such a product are attracted. On the other hand, a poor variety, such as Half and Half, makes an undesirable reputation for a community and its product is discriminated against and sells for a low price.

For a number of years numerous varieties of cotton have been grown at the West Tennessee Station. Of those tried long enough to warrant substantial evidence, the four best are Express, Trice, Cleveland, and a strain of Mexican Big Boll received from the North Carolina Experiment Station. Trice and Express are the earliest. One yields about as much as the other, but the lint of Express is appreciably longer than that of Trice and brings a higher price. The highest yielders have been Cleveland and the Mexican Big Boll, but neither produce lint equal in quality to that of Express. They are not advised for counties north of those where cotton has long been grown. At Knoxville, for example, both Express and Trice are considered more reliable. Trice and Express are well suited to both bottom land and upland. The former is a native variety and slightly earlier than the latter. Express has been highly recommended by the Mississippi Station, and seems to be especially well suited to alluvial or "delta" land. Objections to it are: (1)

It is somewhat hard to pick; (2) the percent of lint is low; and (3) the bolls are inclined to be small. In none of these respects, however, is Trice materially better. Also Trice is more susceptible to disease than any of the others. The superior lint of Express is considered to outweigh the defects mentioned.

Both Cleveland and the North Carolina strain of Mexican Big Boll have good-sized bolls and are appreciably easier to pick than either of the other two varieties. In this respect Mexican Big Boll excels. Both are recognized as excellent upland varieties and according to the North Carolina results one yields as well as the other.

In this connection it should be mentioned that several strains of Cleveland are on the market and that "Wanamaker" Cleveland appears generally to be given the preference. The strain of Mexican Big Boll is not as readily obtained as that of the other varieties, but an effort is being made to have it grown extensively in West Tennessee this season.

Since a number of important items enter into the selection of a variety, Table VII. has been prepared to show the comparative qualities of the four varieties mentioned.

Table VII.
Comparison of Four Leading Varieties of Cotton

| Variety | YIELD PER ACRE | | Percent of Lint | Length of Staple in inches | Relative* Earliness | Number Bolls per pound of Seed Cotton |
|---------------|----------------|------|-----------------|----------------------------|---------------------|---------------------------------------|
| | Lint | Seed | | | | |
| | lb. | lb. | | | | |
| Trice | 568 | 1164 | 32.8 | $\frac{7}{8}$ —1 | 100 | 71 |
| Express | 563 | 1270 | 30.7 | 1—1- $\frac{1}{8}$ | 94 | 74 |
| Cleveland | 608 | 1026 | 37.2 | $\frac{7}{8}$ —1 | 88 | 62 |
| Mexican B. B. | 635 | 1240 | 34.1 | $\frac{7}{8}$ —1 | 86 | 60 |

*Based on the amount of cotton open by the middle of October. According to data collected for ten years at the West Tennessee Experiment Station. The average amount of Trice open at this time was 77½ percent of the total crop.

Notes on Other Varieties

The University of Georgia has recently introduced a promising variety called College No. 1. It is early, has good-sized bolls and is said to be above the average in productiveness. It has not been tested by the Tennessee Station, so that its adaptability to this State in comparison with others is not known.

Acala is extensively grown in Oklahoma and has been tried for a few seasons at the West Tennessee Station. It has about the same length of season as Cleveland, but has considerably larger bolls, which reduce the labor of picking.

Half and Half is to be avoided, chiefly because of its inferior length of staple. The per cent of lint in seed cotton is about the same as for Cleveland, but the yield per acre is considerably less. Also it was found to be under that of Trice.

BOLL WEEVIL CONTROL

The boll weevil is decidedly the worst insect pest of cotton. This insect probably reached every cotton field in the State last year. The first season the damage is little or none, because the dispersion of the weevil to distant fields does not take place until late summer. They will be found in new fields chiefly in immature bolls, which probably would not open were there no weevil. The second year the weevil emerges from winter quarters, enters the nearest fields, and until dispersion time does not distribute itself widely, but does the most damage in small isolated fields, or on the borders of a large field, the center of which may be uninfested. In this way small fields bordering woodland or other suitable hibernating areas may be badly damaged, while other and more distant fields will escape.

Various indirect methods of combating the weevil have been tried out and some have been found to be worth while. The early destruction of cotton stalks is advisable. Clearing and draining land is found profitable on large cotton plantations, because they reduce the opportunity of the weevil to survive the winter. For the reason mentioned large fields can be more easily controlled than a number of widely separated small fields.

The most efficient means of combating the weevil is through the judicious use of calcium arsenate. The Bureau of Entomology of the U. S. Department of Agriculture has done a great amount of investigational work on this subject and their recommendations are considered to be the most reliable that are available at this time. The Bureau's method is to apply the arsenate powder to the plants by dusting. Since there are numerous important items to be taken into consideration no attempt will be made here to give further information, but the reader is referred to a revision of Farmers' Bulletin No. 1262, which is now in press and can be obtained by writing to the Division of Publications, U. S. Department of Agriculture, Washington, D. C.

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University of Tennessee
AGRICULTURAL EXPERIMENT STATION
Knoxville

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THE STRAWBERRY CROWN BORER
IN TENNESSEE

By
S. MARCOVITCH



Strawberry split open showing the larva of the
crown borer within.

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The Agricultural Building, containing the offices and laboratories of the Experiment Station, the College class rooms, and the headquarters of the Division of Extension, is located at the University Farm on Kingston Pike, about one mile west of the main campus. Farmers are cordially invited to visit the building and the experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

THE STRAWBERRY CROWN BORER IN TENNESSEE

By
S. MARCOVITCH

SUMMARY LIFE-HISTORY

1. The strawberry crown borer (*Tyloderma fragariae* Riley), a native American wingless insect, is known to be a pest of old strawberry fields.

2. In Tennessee the crown borer has become so very abundant in certain localities that the mother plants of the newly set fields become severely infested, and as a result put out few or no runners. In Tennessee, strawberry patches are generally picked three years, but when infested with the crown borer the plants often die after the first year.

3. Under experimental conditions, plants affected with the crown borer produced an average of 7.1 runners by September, as compared with 42.1 produced by plants free from the borer.

4. The strawberry crown borer occurs over the whole of the United States east of the Rocky Mountains, but is not reported from Canada.

5. The strawberry is the only cultivated plant known to be infested by the crown borer. Under experimental conditions, however, the adults oviposited on the Indian strawberry (*Duchesnia indica*) and fivefinger (*Potentilla pumila*) from which adults were later bred. It was also observed that the adults will feed on the blackberry, both in the field and in rearing cages. Since the blackberry is rather common around strawberry fields in Tennessee, it becomes possible for the adult crown borer to crawl long distances until a strawberry patch is located.

6. The adult of the strawberry crown borer is one of the snout beetles, related to the plum curculio. It is about one-fifth of an inch in length, of a dark-brown color, and with three transverse dark spots on each elytra. When ready to oviposit, the female bores a hole in the crown, deposits an egg in it, and then covers it over with bits of tissue or dirt. The total time required to deposit an egg is about one hour and forty minutes.

NOTE.—The author wishes to express appreciation to Prof. R. Matheson, of Cornell University, for carefully reading and correcting the manuscript.

7. The average number of eggs laid is 95.3. The egg stage was found to vary from 7 to 29 days, depending on the temperature. Upon hatching, the young larva crawls inside the crown of the strawberry and devours the contents. When two or more larvae are present, a plant will become greatly weakened, or succumb entirely.

8. The larval stage was observed to vary in length from 24 to 54 days; the pupal stage from 6 to 17 days.

9. In a normal year, the adult beetles make their appearance and become actively engaged in ovipositing about the first week in April. This period usually coincides with the beginning of the flowering of the strawberry. Egg-laying continues to the end of September, while larvae may be present from April to the last of November.

10. Hibernation takes place in the adult stage in the strawberry patch beneath leaves and rubbish.

11. The strawberry crown borer is almost free from natural enemies. Two hymenopterous larvae were obtained from two adult beetles on March 7, but these were not reared.

12. The life-cycle is generally believed to be one year. During the course of this investigation several females lived through the winter, after ovipositing in the preceding summer, and continued to oviposit the following spring.

CONTROL

13. Plowing under an infested patch of strawberries will not destroy the adults, particularly if the soil is dry. Instead, by taking away their food supply, it will create a center of distribution from which adjoining patches may become infested.

14. The beetles are unable to emerge when buried from 3 to 6 inches deep in moist or compacted soil; but loose, dry soil offers little resistance to the emergence of the adults.

15. Old infested or abandoned patches should be plowed in late fall or early winter, when the beetles are dormant, and immediately harrowed. Subsequent rains will help to compact the soil and make it difficult for the adults to emerge.

16. The greatest precaution should be taken to secure plants from uninfested patches. It is not a good practice to take plants from old fields for setting, since they are more likely to contain crown borers. At digging time it is advisable to free the plants as much as possible from dirt, as overwintering beetles may adhere to the soil.

17. The strawberry crown borer possesses only very small vestigial wings, and is therefore unable to fly. New plantings may be

protected from its ravages if the beds are set at a distance of 300 feet or more from any old or abandoned patches. If wild blackberries are present new patches may have to be set at a greater distance, as the adult beetles will feed on blackberry, on which they can sustain themselves. The most serious infestations were always found where an old patch adjoined a new patch.

18. In Tennessee new plants for setting should be dug before April 1, at which time the adults begin to oviposit.

19. The beetles feed on the leaves and pedicels, so that spraying with arsenicals will kill them. It is doubtful whether it would pay to spray or dust for the crown borer alone, since it requires several heavy applications to get results, but when used in connection with the strawberry weevil, it would be a good supplementary measure to destroy many of the adults. The eggs of the strawberry crown borer are not killed when dipped for ten minutes in a solution of nicotine sulphate 1-300 plus soap.

20. Tennessee is by far the leading strawberry-producing state in the Union. Through the growing of strawberries as a field crop, with large acreages, and with no system of rotation, ideal conditions are afforded for the strawberry crown borer to become a serious pest.

INTRODUCTION

The strawberry crown borer, a non-flying insect, has become a very serious menace to strawberry production in Tennessee, due largely to the extensive planting of strawberries and the presence of old and abandoned patches. In most parts of Tennessee no system of rotation is practiced, and because of ignorance regarding the borer new patches are planted indiscriminately, usually being placed next to old patches, or adjoining a neighbor's patch. Infestation of new plantings thus takes place, with the consequent reduction in the number of runners produced. In cases of extreme abundance of the borers, it becomes difficult to obtain a stand. Within recent years large acreages and mass production of berries have been depended upon rather than yield per acre, so that all, or nearly all, the cultivated land of a grower may be, or has recently been, in berries. Such a practice, when the acreage under cultivation is small, soon causes the whole farm to become completely infested, so that the planting of new fields at a distance from old patches is out of the question. It is natural to expect to find an insect in abundance where a single crop is grown as extensively as the strawberry is in Tennessee.

CLASSIFICATION

The strawberry crown borer (*Tyloderma fragariae* Riley) is one of the snout beetles of the suborder Rhynophora. In this group

belong some of the worst pests, such as the cotton boll weevil, strawberry weevil, and plum curculio. In 1871 C. V. Riley (1) first described the crown borer from Missouri under the name of *Analcis fragariae*. It was subsequently placed in the genus *Tyloderma* by Casey (7) in 1892. The strawberry crown borer is rather closely related to the plum curculio, for both are placed in the tribe Cryptorhynchini of the family Curculionidae.

HISTORY

The strawberry crown borer is a native American species. Although Riley (1) described the borer from Missouri in 1871, he mentions the fact that in 1868 a ten-acre field was destroyed by it in southern Illinois. The crown borer was reported from Vermont in 1877, and from Ohio in 1879. It had become generally destructive by 1882 in Illinois, where the best account of this insect appears in Forbes's report (2). Bruner (3) records it from Nebraska in 1888. In 1889 it was reported from Kentucky and Indiana. Since then it has been recorded from Rhode Island, 1893; North Carolina, 1893; Arkansas, 1894; Minnesota 1899; New York, 1899; Colorado, 1902; South Carolina, 1909; Virginia, 1909; Kansas, 1913; and Kentucky, 1921.

Many of the references to the strawberry crown borer are very vague, so that it is hard to tell whether or not the insect actually occurs in a given state. It was learned through correspondence, for example, that the strawberry crown borer does not occur on the Pacific coast, although in 1890 it was recorded from Oregon.

GEOGRAPHIC RANGE

According to the foregoing records, the present known distribution of the strawberry crown borer is from Vermont to South Carolina, and west to Colorado and Minnesota. As yet this insect is not known west of the Rocky Mountains nor in Canada.

It has apparently been present in Tennessee for some time, for it was found in destructive numbers throughout the State in 1920. It was found particularly injurious to the new patches in certain sections of both East and West Tennessee. In East Tennessee, injury by the crown borer has been observed at Knoxville, Dayton, Sale Creek, and Chattanooga. The principal localities where the crown borer has been found injurious in West Tennessee are Jackson, Humboldt, Milan, Gibson, Greenfield, Bells, Gadsden, Ripley, and Henning. An infestation was also found at Lancing, in Morgan County, on the Cumberland Plateau. Curiously enough, it was not found in the strawberry section of Middle Tennessee, which centers around Portland.

LOSSES

The strawberry crown borer has proved itself to be a limiting factor in the production of a stand of plants. During September, while inspecting new strawberry fields, from which plants were to be sold, the writer encountered several fields with from one-fifth to three-fourths of a stand. The mother plants looked unhealthy and had produced very few or no runners. In practically every plant dug up, one or more borers were found. In some instances so few runners were present that new fields set in the spring had to be plowed up in September because there were not enough plants to yield profitably.

The strawberry crown borer is more abundant in the older sections of the commercial strawberry centers of Tennessee, such as at Humboldt, Ripley, and Dayton. A note received from Mr. W. H. Bales, of Dayton, expresses concisely the crown borer situation.



Part of young strawberry patch at Dayton, Tenn., planted in spring of 1921, showing a very poor stand due to the injury caused by the strawberry crown borer. Photograph was taken in September, 1921. This end of field is bordered on two sides by old, abandoned strawberry patches.

"Dayton, Tenn., July 4, 1921.

"Director of the Agricultural Experiment Station,
"Knoxville, Tenn.

"Dear Sir:

"Your man has been here looking over our berry fields. I am the largest grower around Dayton, and our worst insect trouble is the crown borer. As much as 15 acres has been lost in one season by one of my neighbors. It is damaging me to $\frac{1}{2}$ stand this year on some of my fields. I think it is the most important enemy to get rid of, as the other strawberry insects do only minor damage in this locality.

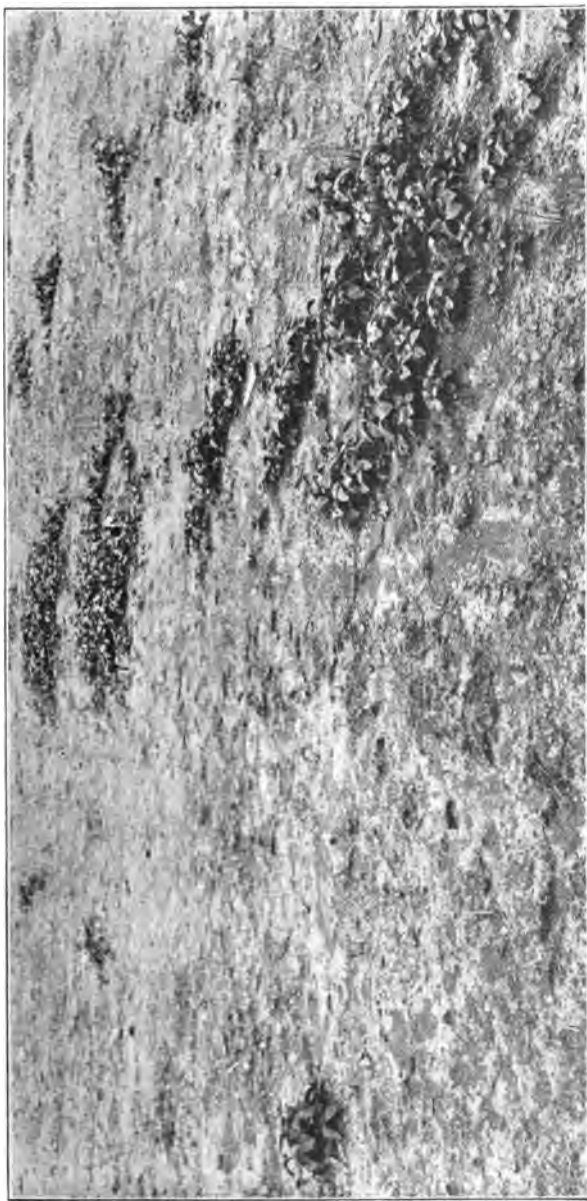
"Very truly yours,

"W. H. BALES."

During the summer of 1921 the exact effect of the crown borer in limiting the production of runners was tested experimentally. Six plants were planted in April, on each of which were placed two crown borers. Wire cages were then set over the plants. A large number of plants were set out about the same time as checks. Table 1 indicates the number of runners produced at certain intervals. On August 1, the checks showed an average of 15.5 runners, while those plants affected with the crown borers had produced only 2 runners. A few of the plants were killed before they produced any runners. By September first, the checks averaged 34.6 runners, as compared with 6.3 runners of the plants affected with the borer. During the season of 1922 the experiment was repeated on a large scale. The same striking results were obtained, the checks having produced 49.7 runners by September 16, as against 7.9 runners.

That the crown borer is a factor in cutting down the yields of strawberries in older fields is generally recognized; yet no exact information is available on this point. Examinations of two- and three-year-old fields have revealed practically every plant infested. In times past, these older fields have often yielded better than new fields, but this is not the case where the crown borer had obtained a foothold. It was observed that an infested plant frequently attempts to outgrow the injury by forming a new crown, which projects out of the ground. Such a plant has the roots exposed and is at the mercy of dry weather.

It has been the practice of the strawberry growers in Tennessee to pick their patches three or four years, but during the past year several fields that have been picked but twice, or even once, in some cases, were plowed under. The reason given was that Lespedeza had taken the bed. In reality an examination proved that the few plants present were infested with the crown borer, and the missing plants had been killed by it. Under such conditions it is but natural for Lespedeza to creep in and take a patch.



Experimental plot showing effect of the strawberry crown borer on the production of runners. Note the small number of runners produced by plants affected with the borer (left), as compared with those of the check row (right).

TABLE 1—SUMMARY OF THE EFFECTS OF THE STRAWBERRY CROWN BORER ON THE PRODUCTION OF RUNNERS IN 1922

| No. | Treatment | Date of planting | No. of runners produced Sept. 16 | Average No. of runners | Total average for 1921 and 1922 |
|-----|----------------------------------|------------------|----------------------------------|------------------------|---------------------------------|
| 1 | Check | March 28 | 7 | | |
| 2 | " | " | 5 | | |
| 3 | " | " | 4 | | |
| 4 | " | " | 9 | | |
| 5 | " | " | 32 | | |
| 6 | " | " | 120 | | |
| 7 | " | " | 110 | | |
| 8 | " | " | 28 | | |
| 9 | " | " | 85 | | |
| 10 | " | " | 22 | | |
| 11 | " | " | 55 | | |
| 12 | " | " | 38 | | |
| 13 | " | " | 24 | | |
| 14 | " | " | 72 | | |
| 15 | " | " | 18 | | |
| 16 | " | " | 12 | | |
| 17 | " | " | 70 | | |
| 18 | " | " | 28 | | |
| 19 | " | " | 52 | | |
| 20 | " | " | 82 | | |
| 21 | " | " | 78 | | |
| 22 | " | " | 88 | 49.7 | 42 |
| | Date of placing adults on plants | | | | |
| 23 | April 12 | " | 0 | | |
| 24 | " | " | 6 | | |
| 25 | " | " | 13 | | |
| 26 | " | " | 19 | | |
| 27 | " | " | 18 | | |
| 28 | " | " | 17 | | |
| 29 | " | " | 15 | | |
| 30 | " | " | 13 | | |
| 31 | " | " | 7 | | |
| 32 | " | " | 12 | | |
| 33 | " | " | 13 | | |
| 34 | " | " | 2 | | |
| 35 | " | " | 4 | | |
| 36 | " | " | 2 | | |
| 37 | " | " | 0 | | |
| 38 | " | " | 6 | | |
| 39 | " | " | 8 | | |
| 40 | " | " | 1 | | |
| 41 | " | " | 7 | | |
| 42 | " | " | 3 | | |
| 43 | " | " | 6 | 7.9 | 7.1 |

STAGES

THE ADULT

Color.—General coloration chestnut brown; head and thorax pitchy black; antennae brownish, with the club darker; legs and elytra chestnut brown—the latter with 3 transverse dark spots on each side, one on basal third that may extend to the base of the elytra, one at the middle, and the third and smallest at the apical third of the elytra. These spots are separated by a whitish pubescence in the form of transverse bands.

Description.—Head not so coarsely punctured as the thorax. Beak slightly longer than head and covered with a whitish pubescence, which becomes longer toward the tip. Scape of antennae about half the length of the funicle, thickened apically; funicle 6-jointed, the first joint the longest and stoutest; joints 3-6 of funicle subequal; club short, compact, with the sutures hardly visible; eyes in repose more or less covered by post-ocular lobes.

Thorax about as long as wide, slightly swollen across the middle when viewed from the dorsal side; less coarsely punctured toward the head. Elytra oval, unevenly pubescent; widest toward the basal third. Disc with 9 rows of punctured striae, the punctures becoming coarser toward the base. Mesosternum with a shallow emargination receiving the beak in repose. Second ventral segment longer than the third. Femora unarmed; tibiae armed with a hook at the tip; tarsi dilated, with the third joint bilobed; tarsal claws simple, small.

Measurements.—Female—length, 4.5 mm; width, 2.2 mm.

Male—length, 3.5 mm; width, 1.6 mm.

THE PUPA

Color.—Creamy white, similar to larva. Eyes conspicuously black. Mandibles and bristles brownish. When pupation takes place, the general coloration is whitish. After a day or two the eyes turn dark, followed by the mandibles, beak, and elytra, until, just before emerging, the insect becomes almost wholly dark.

Description.—Beak rests on venter of body and reaches to front coxae. Tip of antennal club hardly reaches beyond the tip of the beak; the latter with two rows of bristles, which extend over the head. Prothorax supplied with 3 transverse rows of about 4 or 5 bristles. Each femur also supplied with a bristle near its distal end. A transverse row of bristles extends across the mesothorax and metathorax, while the posterior edge of each abdominal segment bears a row of smaller bristles. The last abdominal segment is prolonged into two incurved hooks, one on each side. The elytra are

placed obliquely against the body and extend between the second and third pairs of legs.

Measurements.—Female—length, 5-6 mm; width, 2.4-2.6 mm.

Male—length, 4-5 mm; width, 2-2.2 mm.

THE LARVA

Color.—General coloration whitish, sometimes tinged with orange; head yellowish; mandibles dark brown, with edges darker; maxillary and labial palpi yellowish; eyespot surrounded by a light circular area; epicranial and frontal sutures light yellowish; prothorax with a light brown chitinized shield on the dorsum.

Description.—Body cylindrical and curved toward ventral side, becoming almost straight when about to pupate; surface of body wrinkled, with a depressed lateral line visible from the second thoracic to the eighth abdominal segment; head about as broad as long; antennae very small, one-jointed, and situated at base of mandibles; mandibles bidentate.

Legs wanting, but represented by fleshy protuberances, each bearing several bristles. Side of thorax with an oblique spiracle near the head. First eight segments of abdomen have also a spiracle on each side. Each segment of body covered with a single row of short, sparse hairs.

Measurements.—Length—4.5-6 mm; width 2-2.5 mm.

THE EGG

The egg is of a glistening whitish color, covered with a thick pale-yellow chorion. It measures about 1 mm. in length, and .6 mm. to .8 mm. in width.



Reading from left to right: Adult beetle of the strawberry crown borer (enlarged 5 times). Egg. Larva of the strawberry crown borer (enlarged 6 times). Pupa (enlarged 6 times).

LIFE-HISTORY AND HABITS EXPERIMENTAL

THE ADULT

Feeding Habits in the Spring.—On February 16 several adults were placed on strawberry plants in cages in order that their feeding habits might be observed. They soon began to gnaw holes in the pedicels, on which they fed freely. On February 18 the holes were so large that the pedicels easily broke over when disturbed. The beetles were also observed to feed on the leaves, causing ragged holes, as shown in the photograph. When given whole plants free of dirt, the adults will readily gnaw holes into the roots. The extent to which they feed in this manner in the field has not been determined.

Oviposition—Where It May Take Place.—In the breeding vials, eggs were observed to be deposited in a variety of places. Frequently they were placed within the crown just above the lateral root. Eggs may, however, be deposited anywhere along the crown or in the base of a leaf stalk.

The Act of Oviposition.—On March 10, at 11 a. m., a female was observed to start boring a hole in which to deposit an egg. The place selected was just above the junction of one of the lateral roots with the crown, as shown in the photograph. The process of boring continued until 11:51 a. m., at which time a hole had been formed about as deep as the snout was long. After removing her beak, the female turned around so that the tip of her abdomen rested directly over the hole. She then thrust her ovipositor several times into the hole and finally remained motionless for 8 minutes. Upon laying the egg, she withdrew, and then turned around to cover the egg. This she accomplished by biting off bits of tissue from the lateral roots and surrounding area and tucking them over the egg. Before the egg was half covered her motions were very rapid and nervous. Toward the end the process of covering the egg became more deliberate, and 41 minutes were consumed in the operation. One hour and forty minutes were thus taken to make safe provision for a single egg. Webster records one hour and thirty minutes to complete oviposition. The place selected was at the base of a leaf stalk about one-fourth of an inch above the ground. The egg in that case was covered with mud.

Time Required to Deposit an Egg:

| | |
|----------------------------|------------|
| Excavating Egg Cavity----- | 51 Minutes |
| Depositing Egg----- | 8 Minutes |
| Covering Egg----- | 41 Minutes |

Total ----- 100 Minutes

The method of covering the egg of *T. fragariae* differs considerably from the method of covering the egg of *T. foveolata*, the evening primrose beetle. The latter leaves a conspicuous scar where the egg is deposited, while with *fragariae* the place of oviposition is not apparent in the field. Under laboratory conditions, and on clean plants free of dirt, an egg of the crown borer may be located by the appearance of a small discolored area on the crown.

Number of Eggs Laid.— No definite observations are available on the number of eggs deposited by the crown borer. Webster estimated that a single crown borer may deposit about a dozen eggs during March and April. An attempt was made, therefore, to obtain more exact information in regard to the reproductive capacity of the crown borer. The beetles were supplied with fresh plants once or twice a week and a careful daily examination was made for eggs.

Table 2 gives a record from April 4 to September 27, 1921, for three females that were captured in the field. In all probability they had started to oviposit several days, possibly several weeks, prior to April 4. The average number of eggs laid was 95.3.

Food Plants.—The strawberry is the only host plant of the crown borer that has ever been recorded. Bruner (3) records its occurrence on wild strawberry vines in Nebraska, but in Tennessee the crown borer has been found only in cultivated fields. Garman (8), 1921, states that several closely related plants might possibly be found to harbor the insect and offer a source of infestation. Those listed by him are various species of Cinquefoil (*Potentilla pumila*), Indian strawberry (*Duchesnia indica*), Geum, and Agrimonia.

A search was made for these plants in and around strawberry fields in Tennessee, but their presence was not detected. The only place these plants were found in numbers was on the campus of the University of Tennessee, at Knoxville, where the Indian strawberry was fairly common. It was also present to some extent in and around vacant lots in the vicinity of the campus. *Potentilla* was found more commonly in the mountainous region of East Tennessee. All of these plants were examined, but no borer could be found. It is probable, therefore, that the above plants are not common sources of infestation of the crown borer.

Some of these plants, however, such as the Indian strawberry (*Duchesnia indica*) and Cinquefoil (*Potentilla pumila*), will support the crown borer under experimental conditions. On May 2 several beetles were placed in cages with these plants. They were observed to feed at once on the leaves and pedicel, and May 4 the beetles oviposited on both plants. A larva just hatched was placed, May 6, in the crown of the Indian strawberry. It was observed to feed, and on June 15 it emerged as an adult. The next day a beetle was bred from Cinquefoil. During the course of the breeding of the in-

TABLE 2.—REPRODUCTIVE CAPACITY OF *Tyloclerma fragariae*, 1921

Female No. of

Daily Record—April

| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|-------------|---|---|---|---|---|---|----|
| No. of eggs | | | | | | | |
| 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| 2 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
| 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |

Daily Record—May

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|-------------|---|---|---|---|---|---|---|---|---|----|
| No. of eggs | | | | | | | | | | |
| 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 0 | 2 | 1 | 1 | 1 |
| 2 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| 3 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |

Daily Record—June

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|-------------|---|---|---|---|---|---|---|---|---|----|
| No. of eggs | | | | | | | | | | |
| 1 | 1 | 2 | 1 | 1 | 1 | 0 | 1 | 1 | 2 | 2 | 1 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 0 | 0 | | | | | | | | | | |
| 2 | 2 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 2 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 0 | 1 | 2 | 1 | 0 |
| 3 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 2 | 1 |

TABLE 2—CONTINUED

| Daily Record—July | | | | | | | | | | |
|------------------------|-------------|---|---|---|---|---|---|---|---|---|
| No. of female | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | |
| | No. of eggs | | | | | | | | | |
| | 2 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 0 | 1 | 0 | 1 | |
| | 8 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| Daily Record—August | | | | | | | | | | |
| No. of eggs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | |
| | No. of eggs | | | | | | | | | |
| | 2 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 1 | 0 | 1 | 1 | 0 |
| | 3 | 1 | 2 | 1 | 2 | 2 | 0 | 1 | 0 | 1 | 2 | 2 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | | | | | | | | | | |
| Daily Record—September | | | | | | | | | | |
| No. of eggs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | | |
| | No. of eggs | | | | | | | | | |
| | 2 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | | | | |
| | 2 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | | | | |

TABLE 3.—REPRODUCTIVE CAPACITY OF *Tyloderma fragariae*, 1922

| Daily Record—April | | |
|--------------------|-------------|---|
| | | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | | | | | | | | | | | | |
| No. of female | No. of eggs | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | | | | | | | | | | | | |
| | | 4 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | | | | | | | | | | | | |
| | | 5 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | | | | | | | | | | | |
| | | 6 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | | | |
| | | 7 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | | | | | | | | | | | |
| | | 8 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | | | | | | | | | | | |
| | | 9 | 0 | | | | | | | | | | | |
| Daily Record—May | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | |
| No. of female | No. of eggs | 3 | 1 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| | | 4 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 2 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 2 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| | | 5 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |
| | | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| | | 8 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

TABLE 3—CONTINUED

| Daily Record—June | | | | | | | | | | |
|-------------------|-------------------|---|---|---|---|---|---|---|---|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | |
| No. of female | No. of eggs | | | | | | | | | |
| | 3 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 0 | |
| | 4 | 0 | 2 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | |
| | 5 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | |
| | 6 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | |
| | 7 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 2 | 1 | 0 | 1 | 0 | 1 | |
| | 8 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 2 | |
| | Daily Record—July | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| No. of eggs | No. of eggs | | | | | | | | | |
| | 4 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| | 5 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 2 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 |
| | 6 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
| | 7 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | | | | | | | | | | | | | | | | |
| | 8 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |

TABLE 3—CONTINUED

Daily Record—August

| No. of female | No. of eggs | | | | | | | | | |
|---------------|-------------|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | |
| 4 | 1 | 2 | 2 | 1 | 2 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | | | | | | |
| 5 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | |
| 6 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| 7 | | | | | | | | | | |
| 8 | 0 | 0 | 1 | | | | | | | |

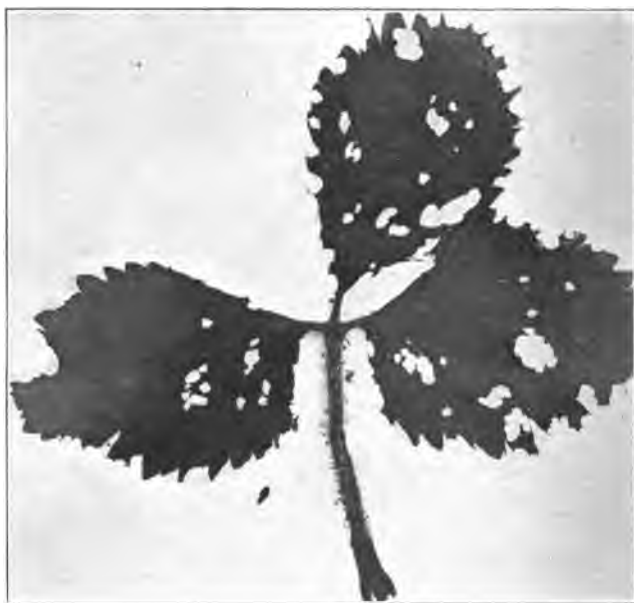
Daily Record—September

| No. of female | No. of eggs | | | | | | | | | | | | | | | | | |
|---------------|-------------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 6 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |

sect in these plants, the larvae were given new plants several times, because the crowns of these plants are so small as compared with the strawberry that it was thought they would not support the larvae to maturity.

In order to test the preference of the insects for these plants as compared with the strawberry, several beetles were placed in cages containing the Indian strawberry and the common strawberry. When examined, May 15, three eggs were found on the Indian strawberry and two eggs on the common strawberry. This indicates that the strawberry crown borer will oviposit at least as readily on the Indian strawberry as on the common strawberry.

The common wild blackberry plant was then tested, since this plant occurs abundantly around strawberry fields. In cage experiments, it was observed that the beetles would feed on the leaves and stem and even oviposit on it. After repeated trials it was learned that the larva is unable to exist in the pith of the blackberry or the raspberry.



Work of the beetle on a strawberry
leaf taken from one of the cages.



Work of the beetle on wild blackberry leaf.

Although the crown borer will not breed in the blackberry, the fact that the adult is capable of feeding on it is an important consideration. Formerly it was supposed that the beetles would not feed on any plant but the strawberry, and would therefore starve in their migration, which takes place only by crawling to locate other strawberry patches. With a plant as common as the blackberry to feed on, it is possible for the adults to migrate and still exist for months until a strawberry patch is located. This was actually found to be the case, for in the laboratory, adults existed for several months in a cage with a blackberry. They were also observed to feed on blackberry in the vicinity of strawberry fields at Curve, Tennessee. One infested field in particular, that was plowed in the spring of 1922, was under observation. When it was examined, June 11, the beetles were found on the leaves of the blackberry bordering the plowed strawberry patch, and it was easy to see the ragged holes caused by the feeding of the beetles. The stems were also gnawed in a way characteristic of the adults. Ten adults were counted in a few minutes on the blackberries.

Evening primrose is another common plant about strawberry fields. Neither the adults nor the larvae could be induced to feed on it. A closely related species, however, *Tyloderma foveolata*, is known to breed in the stems of the evening primrose. This species

has been reported as a pest of strawberry in British Columbia. In Tennessee, *Tyloderma foveolata* did not breed in the strawberry, although it did exist and feed on strawberry in the laboratory for several months.

Length of Life of the Adult.—The life-history of the strawberry crown borer has been assumed to be one year; that is, the adults overwinter, oviposit during the spring and summer, and then die. In general this holds true for a large number of beetles, including those related to the strawberry crown borer.

During the course of the breeding work, an attempt was made to ascertain the reproductive capacity as well as the exact date of death of the beetle. The beetles used in the experiment of 1921 continued to live through the winter of 1921-22. One adult (No. 2) oviposited on January 18, and again on January 30, 1922. Another adult (No. 3) began to oviposit April 17, 1922, and continued to oviposit until June 1. The following week No. 3 died, possibly due to lack of care in attending the beetles, although it might have died with the best of attention. This beetle, as shown in the reproductive table, laid 89 eggs in the summer of 1921, and 17 eggs in the spring of 1922.

To test the matter of longevity further, a series of 10 beetles were bred in the summer of 1921. These oviposited the following year, at the end of which five of the beetles died. The remaining five continued to live and oviposit during the spring and summer of 1923.

The evidence at hand shows that it is possible for at least some of the adults to continue ovipositing the following year. This is not without parallel, for in the case of the strawberry root weevil (*Otiorhynchus ovatus*), also a nonflying insect, it was found recently, in Canada, that the adults will oviposit in two successive seasons.

TABLE 4—SUMMARY OF REPRODUCTIVE CAPACITY FOR
THREE INDIVIDUALS

| No. of female | Average daily production for 1921 | Greatest No. laid in one day | Total No. of eggs | Date of death |
|---------------|-----------------------------------|------------------------------|-------------------|----------------|
| 1 | .78 | 2 | 61 | June 30, 1921 |
| 2 | .68 | 2 | 123 | March 22, 1922 |
| 3 | .64 | 2 | 102 | June 4, 1922 |
| Average .70 | | 2 | 95.3 | |

Length of Egg Stage.—The period of incubation of the eggs of the strawberry crown borer appears to vary considerably, being especially dependent on temperature. Under laboratory conditions the extreme range observed in the duration of this stage is from 7 to 29 days, with an average of 14.7 days. In the early spring the mean temperature of March and April varies from 50 degrees F. to 60 degrees F. These low temperatures increase the length of the egg stage, making it as long as in Indiana during May and June. As the temperature increases in the spring the duration of the egg stage lessens. During the latter part of May and June, a mean temperature of from 75 degrees F. to 77 degrees F. prevails. These high temperatures reduce the egg period to from 7 to 9 days.

Table 5 shows the length of the egg stage from March to September.

TABLE 5—LENGTH OF EGG STAGE OF *Tyloclerma fragariae*,
KNOXVILLE, TENN., 1921

| Egg No. | Date of deposition | Date of hatching | Incubation period | Average length of egg stage by months | Mean temperature by months |
|---------|--------------------|------------------|-------------------|---------------------------------------|----------------------------|
| | | | Days | Days | |
| 1 | March 20 | April 18 | 29 | 29 | 59°F. |
| 2 | April 4 | April 28 | 24 | | |
| 3 | April 4 | April 28 | 24 | | |
| 4 | April 5 | April 26 | 21 | | |
| 5 | April 8 | April 28 | 20 | | |
| 6 | April 9 | April 29 | 20 | | |
| 7 | April 9 | May 1 | 22 | | |
| 8 | April 11 | April 30 | 19 | | |
| 9 | April 12 | May 1 | 19 | | |
| 10 | April 12 | May 2 | 20 | | 59°F. |
| 11 | April 13 | April 29 | 16 | 20.5 | |
| 12 | April 15 | May 5 | 20 | | |
| 13 | April 18 | May 7 | 19 | | |
| 14 | April 20 | May 12 | 22 | | |
| 15 | April 23 | May 13 | 20 | | |
| 16 | April 23 | May 15 | 22 | | |
| 17 | April 25 | May 14 | 19 | | |
| 18 | April 26 | May 12 | 16 | | |
| 19 | April 28 | May 16 | 18 | | 66°F. |
| 20 | May 2 | May 18 | 16 | | |
| 21 | May 5 | May 19 | 14 | | |
| 22 | May 9 | May 23 | 14 | | |
| 23 | May 10 | May 24 | 14 | | |
| 24 | May 18 | May 28 | 10 | | |
| 25 | May 19 | May 29 | 10 | | |
| 26 | May 21 | May 31 | 10 | 16 | |
| 27 | May 24 | June 4 | 11 | | |
| 28 | May 24 | June 4 | 11 | | |

TABLE 5—CONTINUED

| Egg No. | Date of deposition | | Date of hatching | | Incubation period | Average length of egg stage by months | Mean temperature by months |
|---------------|--------------------|----|------------------|----|-------------------|---------------------------------------|----------------------------|
| | | | | | Days | Days | |
| 29 | May | 28 | June | 5 | 8 | | |
| 30 | May | 30 | June | 6 | 7 | | |
| 31 | May | 30 | June | 6 | 7 | | |
| 32 | May | 30 | June | 7 | 8 | | |
| 33 | May | 30 | June | 8 | 9 | | |
| 34 | May | 30 | June | 9 | 10 | | |
| 35 | May | 31 | June | 9 | 9 | | |
| 36 | May | 31 | June | 10 | 10 | | |
| 37 | June | 1 | June | 10 | 9 | | |
| 38 | June | 4 | June | 14 | 10 | | |
| 39 | June | 4 | June | 14 | 10 | | |
| 40 | June | 7 | June | 15 | 8 | | |
| 41 | June | 9 | June | 17 | 8 | | |
| 42 | June | 9 | June | 22 | 13 | | |
| 43 | June | 10 | June | 18 | 8 | | |
| 44 | June | 12 | June | 21 | 9 | | |
| 45 | June | 13 | June | 22 | 9 | | |
| 46 | June | 14 | June | 22 | 8 | | |
| 47 | June | 15 | June | 23 | 8 | | |
| 48 | June | 16 | June | 26 | 10 | | |
| 49 | June | 17 | June | 27 | 10 | | |
| 50 | June | 21 | June | 29 | 8 | 9 | 78°F. |
| 51 | June | 23 | July | 3 | 10 | | |
| 52 | June | 24 | July | 2 | 8 | | |
| 53 | June | 25 | July | 5 | 10 | | |
| 54 | June | 28 | July | 6 | 8 | | |
| 55 | June | 29 | July | 7 | 8 | | |
| 56 | June | 30 | July | 9 | 9 | | |
| 57 | July | 1 | July | 9 | 8 | | |
| 58 | July | 2 | July | 11 | 9 | | |
| 59 | July | 7 | July | 15 | 8 | | |
| 60 | July | 11 | July | 22 | 11 | | |
| 61 | July | 12 | July | 22 | 10 | | |
| 62 | July | 13 | July | 23 | 10 | | |
| 63 | July | 17 | July | 25 | 8 | 9 | 79°F. |
| 64 | July | 26 | Aug. | 4 | 9 | | |
| 65 | July | 29 | Aug. | 6 | 8 | | |
| 66 | Aug. | 10 | Aug. | 20 | 10 | | |
| 67 | Aug. | 11 | Aug. | 20 | 9 | | |
| 68 | Aug. | 17 | Aug. | 26 | 9 | | |
| 69 | Aug. | 18 | Aug. | 31 | 13 | 10 | 77°F. |
| 70 | Sept. | 15 | Sept. | 24 | 9 | | |
| 71 | Sept. | 19 | Sept. | 29 | 10 | 9.5 | 77°F. |
| Total average | | | | | 14.7 | | |

Hatching.—Several days before the egg hatches, the head of the embryo, with its mandibles in motion, may be observed through the dense eggshell. It is probably by means of its mandibles that the eggshell is ruptured, and the larva makes its escape. A ragged hole is left in one end of the egg membrane, which otherwise remains intact.

THE LARVA

Feeding Habits.—On hatching, the small larva is of a pale yellowish color, with a large brown head. The dark brown mandibles are also large and conspicuous. The body of the larva tapers toward the caudal end, and measures about 1.1 mm in length. By making a series of worm-like contortions, the larva soon bores its way into the crown and begins to feed on the contents within. Often the small larvae were found to travel in a circle around the crown beneath the epidermis, thus girdling the plant. Three or four larvae may be found in a single plant. In one case one adult and two small larvae were present within a crown.

Growth is not rapid; it requires several months for the larva to complete its growth. At the end of that time a considerable portion of the crown may be eaten out. If two or three larvae invade a plant the interior may be completely destroyed, and the plant succumb. Since the crown contains the stored food upon which the runners depend for growth it is easy to see why a plant will not produce runners freely when infested with the crown borer. In most cases, the plants are not killed outright, and after the crown borer emerges new roots may be put out and a new crown formed. This new crown is very often an inch or two higher than the old crown. A plant may thus be attacked three or four years successively, at the end of which time the crowns will be found to project several inches out of the ground, with their roots exposed. Such a plant has little chance during dry weather, and is a poor one to depend on for berries. Sometimes an infested plant may form a new plant by stooling.

THE PUPA

Pupation takes place within the crown after growth has been completed. The pupa of the crown borer is more or less active. If disturbed, it wriggles its abdomen back and forth. The length of the pupal stage varies from 6 to 17 days, depending on the temperature.

SUMMARY OF LENGTH OF STAGES

Table 6 gives a record of the time required for the transformation from the egg to the adult form, as determined from rearing records in the laboratory. The total number of days for all the stages varied from 43 in the summer months to 80 in the spring and fall.

The egg occupies an average of 18 days, and varied from 7 to 29 days, depending on the temperature. The time spent in the larval stage varied from 24 to 54 days, with an average of 39 days, while the pupal stage varied from 6 to 17 days, with an average of 11½ days.

TABLE 6—LENGTH OF STAGES OF THE STRAWBERRY CROWN BORER, FROM REARING RECORDS IN 1921

| Date of deposition | Date of hatching | Date of pupation | Date of emergence | No. of days of pupal stage | Total No. days for all stages |
|--------------------|------------------|------------------|-------------------|----------------------------|-------------------------------|
| April 12 | May 2 | June 25 | July 1 | 6 | 80 |
| July 7 | July 15 | August 16 | August 25 | 9 | 49 |
| July 12 | July 22 | August 15 | August 25 | 10 | 44 |
| ? | ? | Sept. 12 | Sept. 19 | 7 | ? |
| ? | ? | Sept. 12 | Sept. 20 | 8 | ? |
| August 10 | August 20 | Sept. 13 | Sept. 22 | 9 | 43 |
| August 11 | August 20 | Sept. 20 | Sept. 29 | 9 | 49 |
| ? | ? | Sept. 21 | Oct. 1 | 10 | ? |
| August 18 | Sept. 1 | Sept. 25 | Oct. 10 | 15 | 53 |
| Sept. 5 | Sept. 15 | Oct. 12 | Oct. 28 | 10 | 53 |
| Sept. 17 | Sept. 26 | Nov. 1 | Nov. 12 | 11 | 55 |
| Sept. 3 | Sept. 13 | Nov. 4 | Nov. 21 | 17 | 79 |
| Sept. 19 | Sept. 28 | Nov. 6 | ? | ? | ? |

SEASONAL HISTORY IN TENNESSEE AS OBSERVED IN THE FIELD

The beetles were first found in active condition on March 20, 1920, in strawberry fields at Curve, Tennessee. A female was found on March 26 in the act of boring a hole in the crown and preparing for oviposition. Eggs were also found on the same date in the field. As indicated by both field and laboratory observations, the beetles become actively engaged in egg-laying in Tennessee about the first week in April of a normal year. At that time, the strawberry is just beginning to put out blooms. In a very early season, such as we had in 1921, oviposition may begin early in March. Cut buds, caused by the strawberry weevil, were conspicuous on March 16, 1921, and it is likely that the crown borer and the weevil begin to oviposit about the same time.

Larvae were found at Dayton more than half grown on May 30, 1921, and on July 1 transformation to the beetle stage was taking place. After July 1, and up to October, the strawberry crown borer may be found in all stages within the crown. Several new patches at Dayton were already invaded on July 5, and showed very few runners. Examination on October 15, 1921, of a large two-year-old field at Lancing, Morgan County, Tennessee, revealed less than half-

grown larvae still present. The crown borers complete their transformation in November, for on November 17 only one larva was found.

Upon transforming to the adult form, several days are required to obtain the natural colors. At first the head is dark red, the thorax and legs are more or less reddish. The elytra are uniformly pale yellowish-brown, and do not acquire the darker characteristic markings until four or five days after the beetle has transformed.

HIBERNATION

With the advent of cold weather, the adult beetles go into hibernation. On February 15, 1921, 21 adult beetles were found in an old strawberry patch. They were most often located on the surface of the soil beneath the strawberry leaves. A few were also found beneath small stones. When taken into the laboratory and placed in cages the beetles burrowed into the soil, so as to be hardly visible.

THE EXTENT OF INJURY AS RELATED TO CULTURAL PRACTICES

Strawberries are treated as a field crop in most parts of Tennessee, and in the majority of cases nothing is done to the fields in the way of renewing after the first year. The weeds are usually mowed off so as to facilitate picking. With but few exceptions fields are allowed to remain in berries from three to five years, and occasionally patches are found much older. Often new patches are "laid by" in August, and nothing further is done to them. By September or October such a dense mass of weeds and grass appears in these new fields that in many instances it is difficult to find the strawberry plants. Old fields in midsummer present the appearance of weed patches. Of course such a system of strawberry culture is not conducive to high yields, so that in order to obtain large quantities of berries mass production is resorted to. Frequently one may find more than half of the total acreage under cultivation on a farm in strawberries. With such conditions prevailing, and with no system of rotation, it is not surprising that the crown borer has become so abundant in certain localities; for more favorable conditions for the breeding of a wingless insect could hardly be obtained. In justice to Middle Tennessee growers, it may be stated that most of their fields were found well cared for; they practice a definite system of rotation; and have no trouble from borers. A visit to Bowling Green, Kentucky, revealed the strawberry crown borer present in some of the fields of that State, as reported by Garman, but in much less abundance than in Tennessee, due largely to the fact that their fields were well cared for and were usually well separated from other patches. They also practice a definite system of rotation.

The foregoing observations show that certain localities may be entirely free from this pest, due no doubt to its inability to fly. On the other hand, where the pest has been introduced with the plants the beetles have multiplied to such an extent that practically every plant may show the effects of the borers. It is estimated that a badly infested patch may contain one-half million crown borers to the acre. Where they have only recently become introduced, or where rotation is practiced, they are found only in the old patches. It is not uncommon, however, to find new fields invaded and destroyed before many runners are put out, particularly where rotation is not practiced and old abandoned patches are left as breeding places. Unless measures are adopted to control the strawberry crown borer, there is every indication that it will prove a limiting factor of first importance in the production of strawberries.

REMEDIAL MEASURES

NATURAL ENEMIES

• The strawberry crown borer is singularly free from predatory or parasitic enemies. Its habit of dropping to the ground when disturbed, and its protective resemblance to the soil, make it inconspicuous to its natural predatory enemies. It is hidden from the sight of most birds because it remains close to the ground while feeding or ovipositing on the crown. Quail have been observed scratching among the strawberry plants, and it is very probable that crown borers may be picked up by them. As yet no parasitic enemies have been reared. A great many borer larvae were examined during different parts of the summer, but in no case was a single parasitized larva found.

On March 7, two hymenopterous larvae about one-fourth inch long were observed in a vial containing adult crown borers which were collected at Dayton in February. These parasitic larvae emerged from two adult beetles which were found to be in a dying condition. Each parasitic larva soon spun a cocoon about itself, but they could not be reared to the adult form. C. V. Riley (1) reared *Bracon analcidis* Ash. as a parasite of the strawberry crown borer in September, 1870.

Several times a small coleopterous larva was found within the crowns infested by the borer. Its exact status was not determined.

EFFECTS OF BURIAL OF THE ADULTS

It is important to know the effects of burial on the adults, for the reason that the old infested beds are frequently plowed up. If it could be shown definitely that plowing under the adult crown borers would destroy them it would aid considerably in diminishing

their numbers. Laboratory experiments were therefore conducted by burial in different soils with different degrees of moisture.

Several adults were placed at the bottom of 5-inch pots and covered with sand and garden soil. The next morning they were all at the surface of the soil. This indicates that dry soil or sand offers little resistance to their emergence. The adults were observed in the act of coming to the surface, and it was noted that they burrowed straight up from where they were placed. Different degrees of moisture were then tried. Several crown borers were placed in the bottom of a large vial 3 inches in length and covered with 26 grams of dry sand, to which was added 8 cc of water. They failed to emerge from this sand, which contained 24 per cent of moisture. The experiment was repeated with 5 cc and 2 cc of water, respectively, and in these cases also the adults were unsuccessful in coming to the top. The borers failed to emerge from sand containing only 8 per cent of moisture.

It appears that the degree of compaction is an important factor in studying the effects of burial. Garden soil containing 20 per cent of moisture was placed loosely over several crown borers in a vial. The next morning the adults were at the surface of the soil. The experiment was repeated, with the same degree of moisture, but with the soil slightly tamped. The crown borers failed to emerge from the compacted soil. Several borers were then placed at the bottom of a vial and covered with air-dried, pulverized clay, which was compacted. The adults failed to emerge from this dry, compacted soil.

To test the effects of burial in the field, a hole was dug 6 inches deep, and five adult crown borers were placed at the bottom and covered with soil, which was in a granular condition, but not wet. Upon examination the next day, not a single crown borer was found at the top of the soil.

The results of these burial experiments indicate that loose, dry soil offers little resistance to the emergence of the adult crown borers, while moist, compacted soil is effective in destroying them when they are buried. Moisture makes the soil more plastic by causing the particles to adhere to each other. Moisture also lessens the size of the air spaces. It appears, therefore, that the adults are not strong enough to move the adhering particles of soil apart when they are held together by moisture or when compacted.

The practical conclusion is that plowing under infested patches does not always destroy the crown borers, particularly if the soil is rather dry and not compacted. It is not safe to depend on plowing to destroy the adults, for unless the field can be dragged and compacted immediately after plowing, any adjoining patches will quickly become infested. This was proved under field conditions at Curve, Tennessee. A badly infested patch was plowed in the spring of 1921 in the usual way, and berries were set in an adjoining field.

From three to five adult beetles were found on June 9 on every mother plant of this new patch, and larvae were present within the crowns. The adults had simply crawled over from the plowed field to the new patch and infested it much sooner than would have been the case had the beetles not been forced to migrate in search of food. The exact time to plow old and abandoned patches infested with crown borers is still in question, but in the light of the above facts it would appear that plowing in late fall or early winter would give the best results. At that time the beetles are dormant, and not as active as during warm weather. This would give more time to get the field harrowed and thus cover the beetles thoroughly. Subsequent rains would then compact the soil and make it difficult for the beetles to emerge.

CLEAN PLANTS

The greatest precaution should be taken to secure plants from uninfested fields. If crown borers are known to be present in a field, even in small numbers, it is unwise to use plants for setting from such a field. Plants should not be taken from old fields, as is sometimes done, because such plants are more likely to be infested. Overwintering beetles may adhere to the soil when the plants are dug, so that it is advisable to free the plants from dirt as much as possible.

SPREAD OF THE ADULTS

The strawberry crown borer possesses very small vestigial wings, about $\frac{3}{4}$ mm long by $\frac{1}{4}$ mm wide. These are far too small to be used for flight, and consequently its only natural means of dispersion must be by crawling. Just how far the adult can crawl in a given time is a bit of information that would be of value in showing how far away to plant new patches from old ones. Some laboratory and field experiments were carried out with this question in mind. A female crown borer was placed on the floor of the laboratory at 3:00 p. m. It crawled back and forth near the spot where it was placed, and at 5:00 p. m., was only $4\frac{1}{2}$ feet away from the starting point.



Left: Dorsal view of the strawberry crown borer with wing covers spread apart to show the undeveloped wings, too small for flight.



Right: Side view of adult, showing manner of playing possum.

The next morning another adult was placed in a large room at 8:15. By 9:01 it had crawled to a spot 20 feet away, where there was a stick, 8 feet long and 1 inch high. The borer crawled back and forth along this stick until 11:15 a. m., but did not crawl over it.

On July 18, at 10:30 a. m., a female crown borer was placed in a field free of vegetation. It crawled very rapidly until it came to a small stick about 5 feet away, under which it took shelter from the hot sun. There it remained for two hours. When the stick was removed the borer crawled nervously around as before. When the stick was replaced, it again crawled under, remaining there until 4:30 p. m., at which time the experiment was discontinued. The adult is evidently not a lover of sunlight.

The next question that presented itself is, how long can the adult live without food? A few old and young beetles were placed in a vial on July 15, 1921, without water or food of any kind. At the end of five days, the old beetles were dead, and at the end of seven days, the young, recently emerged, beetles also died.

Assuming that the beetles can crawl a maximum of 100 feet in a straight line in one day, it is possible for them to crawl 40 rods in seven days. New fields ought to be placed as far away as possible from old strawberry fields. Forty rods or more would seem to be a safe distance. Theoretically, this ought to give perfect protection from the crown borers, but since the adults will feed on blackberry, it is possible for them to sustain themselves for months on this plant, and perhaps on others still unknown. The adults may, therefore, crawl all summer, if necessary, until a strawberry patch is found. That the adults are capable of crawling at least 300 feet was proved at Gadsden, Tennessee, where a two-year-old patch showed the presence of crown borer in the north end of the field. A search northward revealed a five-year-old patch infested which was located about 300 feet away from the two-year-old field. However, it was frequently observed that fields separated by about 300 feet from old fields were comparatively free from borers. In one case a field was separated by only a roadway from an infested patch, and yet no borers were found in this new field. The most serious infestations were always found where the different patches adjoined each other, or where old, abandoned patches were left as breeding places. If a ravine exists in a strawberry patch, the beetles are apt to get washed down toward it, concentrate their work on the plants bordering it, and destroy them, as was noted under field conditions.

The beetles appear to have a tendency to migrate and spread to other places. A field at Dayton, Tennessee, badly infested in 1921, was observed to be comparatively free of the crown borer in 1922. The plants in that field did not look vigorous, owing to the ravages of the borer in the preceding year, and it is possible that the beetles crawled off in search of a better food supply.

EARLY PLANTING

As indicated by the life-history, egg-laying begins early in April. New plants should be dug not later than April 1 in Tennessee, from new fields known to be free from the strawberry crown borer; otherwise the insect may be transported in the egg stage. If the season is very early, egg-laying may begin as early as March 9, as was the case in 1921. The character of the season must therefore be taken into account. In the laboratory, one female laid two eggs during January, and it is possible that during a warm spell in winter, some oviposition will take place in the field. At any rate a few infested fields were found with no adjoining patches, and it is likely that the insect was transported either bodily or in the egg stage.

If late planting must be done, because of weather conditions, and the crown borer is known to be present, it is best to dig up and destroy the mother plants as soon as the runners have taken root.

INSECTICIDES

The beetles will feed on the leaves and gnaw holes in the pedicels, as indicated in the photograph. Poison sprays are therefore suggested as a possible means of killing the adults. In one experiment, a strawberry plant in the field was dusted with 85 parts of sulphur and 15 parts of arsenate of lead on May 16. A second heavy application was given May 20. Examined May 29, four out of five adults were found dead.

Another strawberry plant was heavily dusted in the laboratory on August 10, with calcium arsenate. All of the beetles were found dead August 19. These experiments indicate that it is possible to kill the adult beetles by dusting heavily with arsenicals. Field tests, however, were not as effective as was noted in connection with some dusting experiments against the strawberry weevil. It was not possible to get exact data, but as far as could be ascertained the crown borers were not greatly diminished where they were observed to be abundant. It is doubtful whether it would pay to dust or spray for the strawberry crown borer alone, as the cultural methods of control are more promising. It is very likely, however, that dusting in connection with the strawberry weevil will serve to kill many of the crown borer beetles if they happen to be present.

Nicotine Sulphate as an Ovicide.—The eggs of the strawberry crown borer are laid in a shallow cavity in the side of the crown and loosely covered. If the crown with an egg in it is immersed in a tobacco solution, the egg may come into contact with the solution. Several strengths of nicotine sulphate and soap were used for dipping strawberry plants containing eggs. If the eggs could be killed in this way it would prevent, in a measure, the spread of the

pest through the sale of plants. Table 7 gives a summary of the strengths used and the duration of the immersion.

As will be seen in the table, all of the eggs hatched in all the strengths used. Even a solution of 1 to 300, with the addition of soap for ten minutes, failed to kill the eggs. The egg of the strawberry crown borer is covered with a very thick chorion, which no doubt serves to protect it. In addition, the eggs used were recently laid, being less than a day old. Such eggs are less easily killed than those just ready to hatch. A few eggs were removed from the crown and totally immersed in a 1-to-300 solution of nicotine sulphate and soap for ten minutes. These eggs likewise hatched.

TABLE 7—EFFECTS OF NICOTINE SULPHATE ON EGGS OF *Tyloderma fragariae* (1 DAY OLD) LAID ON CROWN IN LABORATORY

| Exp. No. | Strength of nicotine sulphate used | Date of dipping | Duration of immersion | Date of hatching |
|----------|------------------------------------|-----------------|-----------------------|------------------|
| 1 | 1:300—soap | April 4 | 5 min. | April 28 |
| 2 | 1:300—soap | April 4 | 5 min. | April 28 |
| 3 | 1:300—soap | April 5 | 5 min. | April 26 |
| 4 | 1:600—soap | April 8 | 10 min. | April 28 |
| 5 | 1:600—soap | April 9 | 5 min. | April 29 |
| 6 | 1:600—soap | April 9 | 5 min. | May 1 |
| 7 | 1:300—soap | April 11 | 10 min. | April 30 |
| 8 | 1:300—soap | April 12 | 10 min. | May 1 |
| 9 | 1:300—soap | April 12 | 10 min. | May 2 |
| 10 | 1:1000—soap | April 13 | 10 min. | April 29 |
| 11 | 1:300—soap | April 23 | 5 min. | May 13 |
| 12 | 1:300—soap | April 23 | 5 min. | May 15 |
| 13 | 1:300—soap | April 28 | 5 min. | May 16 |

REFERENCES

1871. Riley, C. V., Snout Beetles: The Strawberry Crown Borer. 3rd Report State Ent. of Mo., pp. 42-44. (Original Description).
1883. Forbes, S. A., The Strawberry Crown Borer. 12th Report State Ent. of Ill., pp. 64-75.
1888. Bruner, L., Report of the Entomologist. Ann. Report Neb. State Board of Agri., p. 129.
1888. Ashmead, W. H., Description of New Species of *Bracon analcidis*. Proc. U. S. National Museum, Vol. 11: 619.
1889. Webster, F. M., Notes on the Breeding and Other Habits of Some Species of Curculionidae, especially of the genus *Tyloderma*. Insect Life, Vol. 2.: 109-112.
1889. Garman, H., Some Pests Likely to be Disseminated from Nurseries. Ky. Agri. Exp. Sta., Bul. 80: 261-263.
1892. Casey, Thos. L., Coleopterological Notices, 4—*Tyloderma*, Ann. N. Y. Acad. Sci., 4:488.
1921. Garman, H., The Strawberry Crown Borer. Ky. Agr. Exp. Sta., Cir. 27: 29-34.



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DARK TOBACCO
FERTILITY EXPERIMENTS AT THE
CLARKSVILLE STATION—RESULTS FROM A
TEN-YEAR PERIOD—1913-1922

By
C. A. MOOERS
AND
R. H. MILTON



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Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

THE SOILS OF RUTHERFORD COUNTY

By
C. A. MOOERS AND H. H. CORYELL

PREFACE

The typical soil of most of the Central Basin is a fertile brown-colored loam underlaid by a yellowish-tinged subsoil. Rutherford County, which is located in the center of this section, is covered in large part by a red or brownish-colored soil underlaid by a red subsoil. That this type is appreciably different from those found in adjoining counties is indicated by the fact that Rutherford County leads all Middle Tennessee counties in the production of cotton. Also it is noteworthy that adjoining counties of the same latitude produce comparatively little cotton. The red land appears to be "earlier," or in some way better suited to this crop, than the other types. Because of the importance of this large body of red land it was decided to map and study it, and to include also in the study all the other soils of the county. This bulletin may be looked upon as a first report of the undertaking.

The soil survey was made in cooperation with the State Geological Survey, Dr. A. H. Purdue, State Geologist. The field work and mapping was done by Mr. H. H. Coryell, under the supervision of Dr. J. J. Galloway, Professor of Geology, Purdue University. The chemical analyses of the soils were made at the Tennessee Agricultural Experiment Station, under the supervision of the Soil Chemist, Dr. W. H. MacIntire. The field experiments were conducted through funds allotted by the State for cooperative experiments in Middle Tennessee. Credit is due to Mr. C. M. Hume and to Prof. H. P. Ogden, of the Middle Tennessee State Normal School, for the careful conduct of the field experiments.

DESCRIPTION OF THE SOILS

Round "chunks" of rock projecting above the soil illustrate the work of the agents of weathering. The surface was once all rock, the cracks and joints in which permitted the rainwater to seep down on its way to the streams. Since water has the power to dissolve and decompose the material of which the rock is made, the joints became deeper and wider, until only an occasional mass of limestone projected here and there. The joints became partially filled by the less soluble portion, the siliceous minerals, iron oxide and other matter, which the water left behind. These "chunks" that still withstand the chemical agents of erosion show the effect of weathering, having a fluted surface, sometimes quite picturesque, as if they had been channeled mechanically.

On the flat, rocky areas where the joints are closed and do not let the rainwater enter and flow into underground channels, "runoff" keeps the fine particles of soil practically all carried away, as is the case with the several acres of rock surface near Murfreesboro, known as the "Center of the State." The surface of the rock becomes warm

and expands during the day, and cools and contracts at night. The water that penetrates the porous limestone freezes frequently during the winter and the ice tends to break off small particles. As the result of this expansion and contraction numerous small flakes of rock are loosened, and on many barren tracts they form an incoherent layer a few inches deep.

Processes like the above and many others of less importance tend to break up the rock into finer and finer particles. The soluble portion is carried away and the residue forms the soil—the deep, loose covering over the bedrock, the upper few inches of which is particularly adapted to supporting and nourishing plant growth. Almost no limestones are pure. On the average, a Central Basin limestone carries 8 per cent of “insoluble” inorganic impurities, which remain in large part as soil, as the lime is slowly leached out and carried away. Therefore 8 tons of earthy substance may be produced from the dissolving away of 100 tons of limestone.

SOIL COLOR

The color of soils has always been a basis for the determination of quality among farmers. The black and brown colors are considered as indications of high productivity. The dark shades are due in large part to the amount of humus matter, which is chiefly derived from decaying plant residues, but also to the amount and chemical form of oxide of iron. Extra-dark-colored lands are usually low lands and very productive. Red land is generally placed next in desirability to the brown lands. In the decomposition of the limestones which formed the majority of the soils of this county the iron impurity was changed to a red-colored oxide, which is present in sufficient amounts to give the soils their reddish color. Those of better grade are of a dark-red, or brownish color, indicating a good supply of humus and high productivity. The lighter red-tinted and gray soils are not usually looked upon with special favor. The lighter color means a scarcity of humus and is usually accompanied by a poor supply of the mineral elements of plant food. Low-lying gray soils are popularly called “crawfishy,” a word which bears a distinctive meaning to all farmers who have had practical experience with such areas. It should be noted, however, that modern agricultural methods can, by proper drainage, fertilizing, and cropping, change the color of a light-tinted soil within a few years, making it become darker-colored and more productive.

SUBSOIL

Frequently there is no definite dividing line between the soil and subsoil, although the majority of the cultivated lands show a fairly distinct line of separation. The soil contains a large quantity of roots, fallen leaves, and stems, which are ultimately converted into humus. The subsoil, on the other hand, is poor in humus. There is a difference in the temperature, moisture, air supply, and presence of organ-

isms in the soil and subsoil. The compactness of the subsoil and the small amount of humus make it less suitable to serve as a seed-bed or to be incorporated into the soil in any considerable amount at any one time. It is called "raw" in comparison with the soil, and not until exposed to the atmosphere and enriched in vegetable matter does it become properly adapted to the functions of the cultivated soil. As the surface soil is lost by erosion the subsoil must more and more be drawn upon to become surface soil. At the same time plant roots penetrate the proper subsoil, deriving from it various elements of plant food and also moisture. If the subsoil be poorly drained so that the water becomes stagnant the roots of most cultivated plants will not penetrate it and tile drainage becomes necessary. Also the subsoil may be well drained but so shallow as not to hold the moisture necessary to tide a crop over a dry spell. For various reasons, therefore, the character, condition, and depth of the subsoil are of great importance.

SOIL VENTILATION

The roots of our cultivated plants must have oxygen from the soil air to produce normal, healthy growth. The soil, therefore, must be porous and accessible to the air. Poor drainage causes insufficient ventilation. The air space becomes filled with water, which prevents the atmosphere from passing in and out. Attention to drainage is often a prime necessity in the production of a fertile soil. With good drainage the roots of many plants penetrate deep into the subsoil, and when they decay leave openings through which the air passes.

SOIL TYPES

RED LAND (RI)*

About one-half of the area of the county is covered with a red-colored soil, which is underlaid by a red subsoil. On the accompanying map this area is colored red. When first cleared the soil was brownish-colored, but with continued cultivation, and little return of organic matter in the form of manure, sod, or green crops plowed under, the color changed slowly to red, which becomes more and more pronounced as the supply of humus decreases. It occupies a belt extending north and south across the central part, with narrow, elongated tracts, along the headwaters of the principal streams, projecting into the "glady" land. In the central area are numerous tracts, varying in size from a few acres to several square miles, of other types of soil, principally the alluvial and "glady" lands, so that the map has a mottled appearance. The red type is the principal agricultural resource of the county, and on it are properly located most of the fertility experiments that are being conducted by the Agricultural Experiment Station. Under present conditions this soil varies from brownish to various shades of red. The surface soil is from four to

*Letters in parenthesis () designate map color.

eight inches deep, and contains enough clay to be easily compacted but enough coarse matter to make it a workable soil, well adapted to numerous crops. The depth of subsoil is variable. Everywhere a limestone forms the bedrock, lying from a few inches to fifteen feet below the surface. The disintegration and decomposition of certain limestones have given rise to the soil. The residue of each of the limestones—Murfreesboro, Pierce, Ridley, Lebanon, Carters, and Cannon—does not as a rule vary enough chemically to make any considerable difference in the soil produced, but by far the largest part of the red land is derived from the Ridley limestone.

The best areas of this type of soil are located south of Dilton, north of Blackman, northeast of Smyrna, and north of Lascassas. Smaller areas, equally good, could be designated in other parts of the county.

Southeast of Gum and east of Christiana is an area of approximately 28 square miles where the soil and subsoil lie upon the Lebanon limestone. The depth to the bedrock varies from a few inches to two feet. Numerous manganese pebbles, or "buckshot," lie over the surface of the soil which has not been broken or cultivated after a few showers of rain. The crops usually suffer from drought, since the soil is not sufficiently deep to retain adequate moisture. The corn grows unevenly, some stalks having a good color and making a fair growth, but many being short and slender and not producing ears. Where depressions exist, the soil is deeper and more fertile. Under good management fair yields of corn and cotton are obtained, but there is much difficulty in getting a good stand of clover. In low, moist areas along the streams where the water does not stand, bluegrass makes good pastures.

Principal Crops Grown

Corn is one of the important crops. Under usual conditions the yield varies from 10 to 40 bushels per acre, but it could be increased considerably by better methods.

Cotton has been for a long time the most important money crop in the county. Year after year it has been grown, in too many instances, on the same field, with the aid of fertilizer only, until little profit is returned. To this kind of cropping can be assigned the cause of the poor condition of much of the lands at the present time.

Clover and grass are grown to a limited extent, but thrive under favorable conditions. Cowpeas, both with and without millet, are much used for hay. Soybeans are being extensively substituted for cowpeas.

Alfalfa has only recently been introduced into the county, but thrives on any well-drained soil that has been made into a good seed-bed and has been limed and inoculated.

Wheat, oats, and other small grains are grown, and, to a less extent, sorghum, crimson clover, and Sudan grass.

"GLADY" LAND (Lc)

"Gladly" land, as the areas of shallow soil, often covered with cedar, are called, is little used for cultivated crops. In fact, there are only spots where the bedrock is entirely covered with soil; that is, more or less rock projects above the surface. This type, colored green on the map, includes all untillable lands. The Lebanon limestone underlies the major part. All the formations, however, contribute to the area. Approximately $\frac{4}{9}$ of the county belongs to this class. Probably $\frac{1}{4}$ of this area can be cleared of rock and become useful for crop production. The "glades" form a belt adjacent to the boundary, varying from three to ten miles in width. The area includes all of the hilly portion, but is not continuous throughout. The stream valleys and sandy soil on the hillsides are occupied by improved farms.

The soil of the Lebanon limestone is seldom deep. Thin, fine-grained slabs of rock are found scattered over the surface and mixed with the soil. The residue from the weathered Lebanon limestone is very fine and light, and the small per cent of oil makes the particles more buoyant. Lateral movement of the ground water is favored by the numerous bedding plains and the inclination of the strata. Therefore, the transportation of the decomposed rock is nearly as rapid as weathering takes place.

In the Ridley limestone area the joints form better passageways for the ground water. Solution takes place along the joints. They are widened and become filled to a considerable depth with soil so that large trees of oak, walnut, and other species find sufficient



One type of glady land



A glady section of the county

food and water there. When joints are few or closed the surface wash removes the decayed rock as fast as it is formed. The exfoliation by the sun's heat covers such surfaces with fine flakes of rock. Vegetation can not therefore grow through the entire summer season, but dies early in the spring. The young roots become dry and stiff and form a characteristic porous layer over the barren patches, which crushes easily. Before the weathering of the rock is complete, many "chunks" project above the surface. Fields of this sort are used principally for pasture.

DARK BROWN 'AND "BLACK" LAND (Rld)

The chrome-green color on the map indicates areas of irregular drained depressions surrounded by the red type of soil. Also it is found along the smaller streams. This soil varies in color from a dark brown to almost black. It is underlaid by a subsoil of dark gray mottled to a bluish black color. The dark color is due to the large amount of organic matter in the soil, and the constant accumulation of plant remains through many years has added fertility as well as intensified the dark color. This type of soil makes some of the best agricultural lands. When well drained it is one of the best for corn, but does not always prove to be a good wheat or oat soil, especially if there are many hard freezes during the winter. Cotton is seldom grown on the black phases, chiefly because it is too wet. Clover and timothy grow splendidly, though it is sometimes difficult to get a stand of clover. Peas, vetch, and other legumes make a luxuriant growth. The largest area of this type lies east of Eagleville. This is without doubt the largest and best general farming community of the entire county, and land values are correspondingly high.

On this type of soil, when it has received proper care, corn yields from 60 to 75 bushels per acre, while the production falls to 35 or 40 bushels on the same soil when poorly managed. Orchards do not grow well on the flat areas.

"BUCKSHOT" LAND (Rlp)

The "buckshot" land is colored brown on the map. It has been rather arbitrarily designated, since in nearly all of the flat areas are found various quantities of brownish-red manganese pebbles, or "buckshot." The areas in which the concretions formed a considerable part of the soil, or would gather in the bottom of all the gullies and small streams in sufficient quantities to form pebble beds of manganese concretions, have been mapped under this type. The productivity does not seem to be affected by the presence of the pebbles. A farm south and east of Rucker produces good crops, while the tract north and east of Gum is not so fertile. Most of the area needs draining.

The soil consists of a clay loam four to eight inches deep, underlain with a heavy mottled clay subsoil. The subsoil shows the lack of aeration and ventilation. The soil is too wet for cotton. Corn and clover produce splendid yields on well-drained tracts.

ALLUVIAL LAND (Al)

Alluvial soil is found along the larger streams of the county. It covers about five square miles, though no area of this type is more than half a mile wide. It is colored yellow on the map.

The surface soil is a light brown, and from six to twelve inches deep. The soil and subsoil are more or less stratified, having been deposited during the high waters of the stream, though the marks of stratification are destroyed at the surface by the processes of cultivation. The subsoil is clayey, but contains appreciable amounts of fine sand and gravel. The soil is easily tilled and can be worked into a fine seed-bed. On the surface is seldom found a continuous hard crust after a rain. This type can be used for several successive corn crops and maintain fair productivity. Clover and oats make good crops to complete the rotation with corn.

The cultivation of tillage crops is at times interfered with by overflows, which carry weed seeds to the silty deposit.

The small tracts furnish some opportunity for intensive farming, though little is used in that manner at present. Some truck crops are found to do well, especially early cabbage and tomato.

"CRAWFISH" LAND (Rib)

The soil colored blue on the map is limited to about two square miles and occupies poorly drained depressions. It contains some organic matter, but not sufficient to produce a dark color. In many places it had been leached to a pale grayish soil, commonly known as "crawfish" land.

It is quite often difficult to determine the division between the soil and the subsoil. In color they are nearly alike, the soil being a little darker gray and not so mottled, with white blotches. A stiff, compact clay layer, called "plowsole," a temporary hardpan, is sometimes found, and is probably due to the breaking of the ground when wet.

This type of soil puddles very easily, and heavy showers of rain will pack the ground so hard that it forms large, deep cracks when it dries. This type was originally covered by trees that thrive in wet soil. The land is level in most places. Open ditches and "dead furrows" provide surface drainage.

When this type is thoroughly drained it proves to be a fair corn, wheat and forage soil. Timothy will grow upon the higher portions of the area, but red top is the grass best suited to it. In areas not adequately drained the corn is at first of a dark green color, but later turns yellow, and the mature plant is small and slender, with yellow leaves.

Within the Eagleville area are many smaller areas of another type of soil not shown on the map. This soil is very dark. The subsoil is a heavy, stiff, plastic black clay when wet, but breaks up into cubical particles when dry. On the surface of this ground, especially on the upper edges of the small "clods," is seen a thin film of whitish inorganic salt. The corn becomes yellow early in its growth. The veins of the corn leaves turn yellow before the chlorophyll green of the rest of the leaf is destroyed. The plant is easily pulled up. All deep roots are dead, and only the surface roots feed the plant. Before maturing, many of the stalks are bent and crooked, and the yield is very light.

It has been found that underground drainage, with tiles only a few rods apart, has in one season made remarkable changes. The stagnant and sour underground water is removed, and every rain washes more of the inorganic salts away. This soil is said to respond to manure and fertilizer.

GRAVELLY LAND (Rg)

On the tops of the hills along the east fork of Stones River, at Jones Mill, south and east of Walter Hill, and east of Compton, are water-worn gravels. These areas are colored light purple on the map.

The area at Jones Mill is the smallest and is of no agricultural value. The others are cleared of timber and used either for pasture or tillage crops. The corn ripens early. An adequate supply of water for the growing crops is dependent almost wholly on the frequency of the rains, for the ground-water level soon sinks far below the roots of the plants and the capillary water evaporates rapidly from this coarse, pebbly soil. It would give better returns to leave these hills in pasture or woodland.

PHOSPHATIC SOILS (H)

On the sides and tops of the hills, in the hilly area that forms a

nearly continuous belt about the borders of the county, are many small areas of a sandy phosphatic soil, designated by a light blue color. It is derived from the decomposition of a sandy phosphate-bearing rock which weathers to a yellowish color. The sand constituent varies in amount. This formation, known as Hermitage, weathers away faster than the limestones above or below it. The area of its outcrop on the sides of the hills is invariably "cleared" and converted into pasture lands or cultivated fields. The soil does not wash and gully readily, and steep hillsides have been cultivated for years without much destruction from surface wash. This type of soil furnishes comparatively good bluegrass pasture during a rainy season.

The nature of the soil is such that tillage crops ripen more than a week before similar crops on the heavier types. Alfalfa grows splendidly on the level portions of this soil where there is adequate supply of water. Such an area is located on the sandy soil north of Liberty Church, three and one-half miles east of Fosterville.

BARRENS LAND (P)

In the southeastern part of the county, south and east of Prater Hill, is a cherty formation (the Fort Payne chert), which gives rise, on the hilltops, to the cherty soil like that of the Barrens of the Highland Rim. These small areas, all of which do not make a single square mile of territory, are of little consequence agriculturally. Crops suffer from drought and give low yield. Corn, sorghum, and millet are the principal tillage crops. Small groves of large chestnut trees cover several acres of this kind of soil. The areas are colored purple on the accompanying map.

CHEMICAL ANALYSES OF SOILS

The chemical analysis of a soil is of value in that it is an index to the total reserve supplies of the various plant-food elements. These supplies may be extreme, either so large as to leave little doubt of their being ample, or so small as to furnish almost conclusive proof of their inadequacy. Under medium or average conditions, however, the interpretation of the analysis should be made very guardedly, especially as the analysis throws little light on the immediate availability of the elements determined. That is, both the chemical combination and mechanical condition in one soil may be decidedly different from those in another. Also a low percentage in a sandy soil may be equivalent to a high percentage in a clay soil, because the plant roots extend to greater breadth and depth in the former than in the latter. The writer considers that a chemical soil analysis is highly valuable in connection with field experiments with lime and fertilizers. In fact, they supplement each other.

Table 2 gives the chemical analyses as made by the acid digestion method for a number of soil samples taken in various parts of the county. Table 1 gives the locality where the samples were taken and descriptive matter relating to them.

TABLE 1—*Information relating to soil samples for chemical analysis as reported in Table 2.*

| Laboratory number | Locality | Soil color | Formation from which derived | Depth to underlying rock | Forest growth | REMARKS |
|-------------------|--|---|--|--------------------------|---|---|
| 4660 | On hilltop 4½ miles N. E. of Murfreesboro. | Light brick red | Carters limestone | 1½-2½ ft. | Black oak, hickory. | Old field planted to corn, 15-20 bushels yield. Found on or near top of some of the highest hills. |
| 4663 | Hall's Hill pike, Taylor's Chapel. | Brownish red. Considerable variation in field | Lebanon limestone | 1-1½ ft. | Cedar, persimmon, hickory, walnut, black oak. | Old field on farm of J. W. Benson. Said to produce 15-20 bushels corn per acre. Typical Lebanon conditions. |
| 4664 | Hall's Hill pike, Taylor's Chapel. | Redder than 4663 | Lebanon limestone | 1-1½ ft. | Cedar, persimmon, hickory, walnut, black oak. | Subsoil to 4663. |
| 4666 | 2½ miles west of Murfreesboro. | Brownish red | Murfreesboro limestone | 2-4½ ft. | Black locust, cedar, hickory. | Old field. Produces 700 to 800 pounds seed cotton or 20-25 bushels corn per acre. |
| 4667 | 2½ miles west of Murfreesboro. | Redder than 4666 | Murfreesboro limestone | 2-4½ ft. | Black locust, cedar, hickory. | Subsoil to 4666. |
| 4668 | 1½ miles N. W. of Almarville. | Yellowish gray | Lower Hermitage (fine sandstone and shale) | 1-4 ft. | Elm, oak, poplar, beech, locust, walnut. | Old field inclined to be wet. On farm of T. E. Newman, Arrington. Corn following clover. Corn good in dry year. Phosphate rock in field. Soil sandy. Both sandy and clayey subsoil. |
| 4670 | Near Armstrong branch, on Franklin pike. | Red | Ridley limestone | | Walnut, hickory, oak. | Old field on farm of J. C. Clark, about 5 miles west of Murfreesboro, on Franklin pike. |
| 4672 | Near Rucker. | Light brown | Ridley limestone | 2½ ft. | Elm, locust, hickory. | Old field on farm of J. E. Hallyburton, Rucker. Said to produce 35-40 bushels of corn per acre. Considerable "buckshot" in soil. |
| 4673 | Near Rucker. | Light brown | Ridley limestone | 2½ ft. | Elm, locust, hickory. | Subsoil to 4673 |
| 4674 | 3 miles N. E. of Eagleville. | Gray | | | | "Crawfishy" soil. In spots over flat land. |
| 4675 | N. E. of Eagleville | Gray | | | | "Crawfishy" soil. Occurs in spots in field. |
| 4681 | 3½ miles west of Christiansana. | Light red | Lebanon limestone | 3-4 ft. | | Subsoil to 4682 |
| 4682 | 3½ miles west of Christiansana. | Light red | Lebanon limestone | 3-4 ft. | | A phosphate soil. Smaller in appearance to 4683. |
| 4685 | 1½ miles west of Almarville. | Yellow gray | Hermitage | | | Old field on farm owned by R. H. Kittrell. |
| 4687 | Near Blackman. | Brownish | Ridley limestone | | | |
| 635 | | Brownish red | | | | |

TABLE 2—*Chemical analysis of soils from Rutherford County soil survey.*

| Soil No. | Insoluble matter and materials soluble in hydrochloric acid of 1.115 Sp. Gr. | | | | | | | Volatile matter | Nitrogen N | Reaction by thio-cyanate |
|----------|--|---|---|----------------------|--------------------------|--------------------------------|--|-----------------|------------|--------------------------|
| | Insoluble residue | Iron and aluminum
oxide
Fe_2O_3 and Al_2O_3 | Manganese
oxide
Mn_2O_3 | Lime
CaO | Magnesia
MgO | Potash
K_2O | Phosphoric
acid
P_2O_5 | | | |
| | | | | | | | | Per cent | Per cent | Per cent |
| 4660 | 84.01 | 10.84 | .26 | .496 | .372 | .164 | .077 | 6.82 | .090 | Acid |
| 4663 | 72.49 | 15.64 | .15 | 1.952 | .776 | 1.090 | .075 | 12.15 | .169 | Sl. acid |
| 4664 | 70.34 | 20.49 | .16 | .848 | .986 | .920 | .063 | 10.85 | .085 | Acid |
| 4666 | 86.97 | 8.72 | .83 | .216 | .296 | .399 | .075 | 8.80 | .085 | Acid |
| 4667 | 83.56 | 12.07 | .21 | .320 | .412 | .332 | .050 | 7.87 | .058 | Acid |
| 4668 | 80.52 | 10.51 | .09 | 1.600 | .562 | .340 | 1.915 | 6.65 | .107 | Str. acid |
| 4670 | 76.80 | 8.74 | .25 | .400 | .800 | .215 | .075 | 11.80 | .089 | Sl. acid |
| 4672 | 86.22 | 7.99 | .15 | .307 | .286 | .222 | .074 | 6.76 | .143 | Sl. acid |
| 4673 | 84.11 | 10.24 | .14 | .480 | .850 | .392 | .064 | 6.37 | .095 | Acid |
| 4674 | 87.69 | 6.26 | .13 | .624 | .381 | .209 | .073 | 8.34 | .179 | Sl. acid |
| 4675 | 78.15 | 11.71 | .13 | .928 | .555 | .591 | .190 | 10.52 | .217 | Str. acid |
| 4681 | 81.42 | 12.93 | .33 | .400 | .429 | .535 | .071 | 6.75 | .097 | Acid |
| 4682 | 79.58 | 14.43 | .25 | .312 | .433 | .352 | .076 | 6.86 | .093 | Acid |
| 4685 | 83.55 | 9.44 | .14 | .928 | .278 | .190 | 1.552 | 5.57 | .071 | Sl. acid |
| 4687 | 83.41 | 9.44 | .22 | .768 | .501 | .134 | .145 | 7.91 | .179 | Str. acid |
| 635* | 81.92 | 10.53 | .33 | .220 | .235 | .294 | .081 | 5.42 | .116 | |

*Per cent sulphur trioxide in soil No. 635 was 0.047.

COMMENTS ON THE ANALYSES

The Insoluble Residue

The insoluble residue is the siliceous matter left after digestion in the strong acid, which is supposed to dissolve all the lime, phosphoric acid, potash, and other mineral elements which can become available for plant use in near future years. As a rule the best soils in the State run from 75 to 85 per cent of insoluble residue—percentages which we find in Rutherford County soils. The poorest soils, on the other hand, generally show 90 per cent or more.

Iron and Aluminum Oxides

Iron is a necessary element of plant food, but only a very small amount is required. Soils like these are looked upon as high in these elements. The red and yellow colors in soils are due to oxides of iron.

Manganese Oxide

Manganese is not a necessary plant-food element, but may play some indirect part in plant growth. These soils are evidently well supplied with it.

Lime

Lime is very important to plant growth. In comparison with other soils in the State these are fairly well supplied. The fact that clover thrives may be considered as corroborative evidence. That the supplies of lime are not great is indicated by alfalfa, which has a higher lime requirement than any other crop, and as a rule requires liming. Two analyses, Nos. 4663 and 4668, show high percentages. These two soils are from the decomposition of a formation which carries deposits of phosphate. This lime is probably combined with the phosphoric acid and therefore not in a form to correct soil acidity.

Magnesia

Magnesia is an important element of plant food. It is found in the seeds of plants in much greater quantity than lime. Magnesia is an essential constituent of the green coloring matter of leaves, and a deficiency of this element gives rise to a disease of tobacco known as "sand drown," which is characterized by a whitening of the leaves between the ribs, a condition more marked in the lower than in the upper leaves. It affects the blades of corn in a similar manner, giving them a more striped appearance than is normal.

These soils appear to be above the average in magnesia content. Little attention has been given to this element until recently and there is the possibility of its being of more importance than has hitherto been realized.

Potash

Potash has long been recognized as an important element of

plant food. A deficiency in the soil shows itself first of all, in wheat, for example, in a decreased growth of stem and leaf, but without a corresponding decrease in grain production. Similarly a deficiency of potash is especially detrimental to a hay crop. Also it is important in the production of potatoes. The table shows Rutherford County soils vary greatly in their supplies of this element. A percentage of 0.25 to 0.40 is rated as good, and those showing more are considered rich in potash; but the analysis is not an infallible guide, so that great stress can not be placed on the results.

Phosphoric Acid

Phosphoric acid is one of the fundamentally important elements of plant food. Plants require only one-fourth to one-half as much phosphoric acid as potash, but the soil supply of phosphoric acid is much more likely to be deficient than that of any other element. A deficiency cuts down not only stem and leaf but also grain and fruit production. Soils 4668 and 4685 are derived from the decomposition of phosphate rock and are exceptionally rich in phosphoric acid. The majority of the soils, however, have poor supplies, and it is not surprising to find that phosphatic fertilizers are in common use.

Volatile Matter

The volatile matter is that part of the soil which is lost when subjected to strong heat. All vegetable matter, also chemically combined water and carbon dioxide, are included. Fertile soils are nearly always high in volatile matter and poor soils low. This is not, however, a good guide because a poor clay, low in vegetable matter, may show a much higher content of volatile matter than a fertile loam. This is due to the large amount of combined water in the clay.

Nitrogen

Nitrogen is another of the very important plant-food elements in the soil. The most marked difference between the chemical analysis of a poor, worn soil and that of fertile new land is the content of nitrogen, the new land being far better supplied than the old land of the same kind. Nearly all the nitrogen is contained in the dark-colored vegetable matter, or humus, of the soil, and the supply in the surface soil is much greater than in the subsoil. Erosion and long-continued cropping in corn and cotton have greatly reduced the nitrogen supply of Rutherford County soils. Such crops as red clover, sweet clover, and alfalfa, also mixed clover and grass pastures, and the application of farmyard manure, are the most important means of restoring nitrogen and thereby building up soil productivity.

Reaction

The reaction of a soil—acid or alkaline—is a good indication of lime requirement. All these soils reacted more or less acid, indicating need of lime.

TABLE 3—Fertilizer and liming experiments with soybeans—yields in tons of hay per acre.

(Fertilizer and liming rates per acre: 300 pounds acid phosphate; 100 pounds muriate of potash; 2 tons ground limestone).

| Farm of | Color of soil | Fertilizer | | | | | | | | | | Remarks |
|---|---------------|------------|---------|-----------|---------|--------|---------|----------------------|---------|----------------------------|--|---------|
| | | None | | Phosphate | | Potash | | Phosphate and potash | | | | |
| | | Limed | Unlimed | Limed | Unlimed | Limed | Unlimed | Limed | Unlimed | | | |
| | | Tons | Tons | Tons | Tons | Tons | Tons | Tons | Tons | | | |
| Prof. P. A. Lyon
(southeastern part of county) | Brown | 1.74 | 1.37 | 1.92 | 1.52 | 1.84 | 1.45 | 1.88 | 1.63 | All crops grown
in 1916 | | |
| A. N. Miller
(west of Rucker) | Red | 1.81 | 1.56 | 2.37 | 1.60 | 1.85 | 1.50 | 2.18 | 1.83 | | | |
| Ed Campbell
(west of Murfreesboro) | Red | 1.50 | 1.20 | 1.82 | 1.48 | 1.19 | 1.05 | 2.86 | 1.42 | | | |
| State Normal Farm
(in Murfreesboro) | Red | 2.41 | 2.17 | 2.81 | 2.67 | 2.32 | 2.06 | 2.85 | 2.22 | | | |
| Average | | 1.87 | 1.58 | 2.28 | 1.82 | 1.80 | 1.52 | 2.32 | 1.78 | | | |

Sulphur

Sulphur is one of the necessary plant-food elements, but was estimated in only one of the soil samples, No. 635. The per cent of sulphur trioxide, 0.047, is small, but is slightly greater than the average from nineteen soil samples from the Central Basin, as reported in Bulletin 78, "The Soils of Tennessee." Thus far in this Station's field experiments the need of addition of sulphur for plant-food purposes has not been demonstrated for any soil in the State. Apparently the natural supplies, together with that brought down in the rainfall, are ample. In this connection mention may be made of the fact that acid phosphate contains nearly 50 per cent of land plaster, or calcium sulphate, a form of sulphur readily utilized by plants.

FERTILIZER EXPERIMENTS ON RED LAND

WITH SOYBEANS

In 1916 four series of field experiments were made to determine the response of soybeans to phosphate, potash, and lime on different farms in the county. Table 3 gives the results obtained.

Results from only a single season afford an indication of soil need, but their value can be easily overrated. In fact, because of seasonal peculiarities and variation in the fertility of the different plots in any series, only general conclusions are warranted. The results of these series, however, are a unit in indicating a general soil need of both phosphate and lime, but no need of potash.

WITH MILLET

In 1910 a series of fertilizer experiments with millet for hay was conducted on the farm of Mr. A. N. Miller, near Rucker. The treatments and yields obtained are given in Table 4.

TABLE 4—*Fertilizer experiments with millet on farm of A. N. Miller, near Rucker.*

(Fertilizer rates and yields per acre)

| Series | Fertilizer | Yield of hay | Remarks |
|--------|---|--------------|---|
| 1 | None | Tons
0.90 | There were five plots in each series; a total of 25 plots being harvested separately to get the data given. The crop was grown in 1910. |
| 2 | 300 lbs. acid phosphate | 1.42 | |
| 3 | 300 lbs. acid phosphate
100 lbs. muriate of potash | 1.38 | |
| 4 | 150 lbs. acid phosphate
100 lbs. muriate of potash | 1.25 | |
| 5 | 600 lbs. acid phosphate
100 lbs. muriate of potash | 1.80 | |

The results show a decided response to acid phosphate, but no increase from potash.

WITH ALFALFA

Table 5 gives the results of fertilizer, lime, and manure experiments with alfalfa, carried out for three years on red land on the farm of the Middle Tennessee State Normal at Murfreesboro. Plots 1 to 5, inclusive, had been limed with ground limestone in 1916 at the rate of two tons per acre. The fertilizers mentioned were applied in the summer of 1920. Seeding was done the same season, a good stand being obtained on all plots.

The results show marked increases from phosphate, manure, and lime, but little or no certain increase from potash.

TABLE 5—Yields of alfalfa in experiments on the farm of the Middle Tennessee State Normal, Murfreesboro—red land.

| Plot No. | Fertilizer treatments per acre | Yields of hay per acre | | | | Notes |
|----------|--|------------------------|------|-------|----------------|---|
| | | 1921 | 1922 | 1923* | 3-year average | |
| 1 | Acid phosphate, 600 lbs.
Muriate of potash, 100 lbs. | 2.57 | 4.20 | 1.76 | 2.84 | Ground limestone applied at the rate of two tons per acre to plots 1-5 in 1916. |
| 2 | Acid phosphate, 600 lbs. | 2.74 | 3.74 | 1.62 | 2.70 | |
| 3 | No fertilizer | 1.87 | 2.90 | 1.18 | 1.98 | |
| 4 | Manure, 12 tons | 4.15 | 4.96 | 2.51 | 3.88 | |
| 5 | Manure, 12 tons | 4.77 | 5.05 | 2.59 | 4.14 | |
| 7 | Acid phosphate, 1200 lbs.
Muriate of potash, 200 lbs. | 1.08 | .85 | .80 | 0.91 | Unlimed—chiefly crab grass |

*First two cuttings.

WITH A FIVE-YEAR ROTATION

Table 6 gives the fertilizer treatments and crop yields obtained in a five-year rotation of wheat, clover and grass (two years), corn, cotton, and soybeans. The experiments were conducted on the farm of the Middle Tennessee State Normal, at Murfreesboro. The rotation was run on each of five different ranges, thus allowing the production of each crop every year. It should be explained, however, that instead of each crop occupying a whole range, as did the other crops, one half of a range was planted to corn and the other half to cotton. Each range in these experiments was divided into thirteen 1/40-acre plots, which were fertilized according to the plan shown in Table 6. Every third plot was a check, or no-fertilizer, plot, there being four such plots to a range. In the table the yields of the no-fertilizer plots were averaged and are not shown in detail.



Alfalfa a failure on unlimed land



Alfalfa a success on limed land

TABLE 6—Fertilizer treatments and yields per acre of the several crops grown in a five-year rotation of corn-cotton, soy-beans, wheat, and clover and grass (2 years) on a brownish-red soil. Experiments on the farm of the Middle Tennessee State Normal, Murfreesboro.

| Series | Fertilizer | Wheat | | | | | | | | | | Clover and grass hay | | | | | | | | | |
|--------|--|---------------------------------|------|-------|------|-------|------|-------|------|----------------|------|----------------------|------|------|------|------|------|------|------|----------------|------|
| | | 1920 | | 1921 | | 1922 | | 1923 | | 4-year average | | 1920 | | 1921 | | 1922 | | 1923 | | 4-year average | |
| | | Grain | | Grain | | Grain | | Grain | | Grain | | Grain | | Staw | | Staw | | Staw | | 4-year average | |
| | | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons |
| 1 | Acid phosphate | 200 lbs. | 8.4 | 0.93 | 20.7 | 1.60 | 17.5 | 0.98 | 16.0 | 1.50 | 15.7 | 1.25 | 0.86 | 1.69 | 2.78 | 2.52 | 1.96 | | | | |
| 2 | Acid phosphate
Muriate of potash | 200 lbs.
25 lbs. | 10.6 | 0.96 | 21.4 | 1.71 | 13.2 | 1.21 | 18.3 | 1.47 | 15.9 | 1.34 | 0.87 | 1.35 | 2.94 | 2.44 | 1.90 | | | | |
| 3 | No fertilizer (average of
4 check plots) | | 9.4 | 0.82 | 12.8 | 0.91 | 6.3 | 0.80 | 7.8 | .77 | 9.1 | 0.83 | 0.53 | 1.00 | 1.82 | 1.44 | 1.20 | | | | |
| 4 | Nitrate of soda | 100 lbs. | 6.3 | 0.61 | 12.3 | 1.00 | 8.6 | 1.14 | 7.0 | .73 | 8.6 | 0.87 | 0.67 | .81 | 2.02 | 1.76 | 1.82 | | | | |
| 5 | Acid phosphate
Nitrate of soda | 200 lbs.
100 lbs. | 12.4 | 0.88 | 17.2 | 1.37 | 13.0 | 1.06 | 17.3 | 1.42 | 15.0 | 1.18 | 0.73 | 1.81 | 2.96 | 1.40 | 1.78 | | | | |
| 6 | Muriate of potash
Nitrate of soda | 25 lbs.
100 lbs. | 8.1 | 0.63 | 15.3 | 1.07 | 6.5 | 0.82 | 11.1 | 1.12 | 10.3 | .91 | 0.37 | 0.60 | 2.08 | 1.08 | 1.03 | | | | |
| 7 | Acid phosphate
Muriate of potash
Nitrate of soda | 200 lbs.
25 lbs.
100 lbs. | 10.2 | 0.88 | 20.8 | 1.48 | 12.0 | 1.03 | 23.2 | 1.88 | 16.6 | 1.32 | 0.51 | 1.88 | 4.16 | 1.94 | 2.12 | | | | |
| 8 | Acid phosphate
Nitrate of soda | 400 lbs.
200 lbs. | 6.6 | 0.70 | 19.1 | 1.44 | 16.3 | 1.41 | 14.0 | 1.30 | 14.0 | 1.21 | 0.53 | 1.76 | 4.71 | 2.68 | 2.42 | | | | |
| 9 | Acid phosphate
Muriate of potash
Nitrate of soda | 400 lbs.
25 lbs.
200 lbs. | 9.9 | 0.70 | 26.5 | 1.96 | 16.6 | 1.57 | 14.8 | 1.38 | 17.0 | 1.40 | 0.46 | 2.35 | 5.44 | 2.36 | 2.65 | | | | |

TABLE 6—(Cont.)—Fertilizer treatments and yields per acre of the several crops grown in a five-year rotation of corn-cotton, soybeans, wheat, and clover and grass (2 years) on a brownish-red soil. Experiments on the farm of the Middle Tennessee State Normal, Murfreesboro.

| Series | Fertilizer | Corn | | | | | | | | | | Seed cotton | | | | Soybean hay | | | | | |
|--------|--|-------|--------|-------|--------|-------|--------|-------|--------|---------------|------|-------------|--------|------|------|-------------|------|------|------|----------------|------|
| | | 1920 | | 1921 | | 1922 | | 1923 | | 4-yr. average | | 1920 | | 1921 | | 1922 | | 1923 | | 4-year average | |
| | | Grain | Stover | Grain | Stover | Grain | Stover | Grain | Stover | Bu. | Tons | Grain | Stover | Bu. | Tons | Lbs. | Lbs. | Lbs. | Lbs. | Tons | Tons |
| | | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons | Lbs. | Lbs. | Lbs. | Lbs. | Tons | Tons |
| 1 | Acid phosphate 200 lbs. | 65.8 | 1.60 | 43.5 | 1.34 | 39.7 | 1.14 | 36.1 | 0.91 | 46.3 | 1.25 | 1591 | 2180 | 973 | 576 | 1881 | 1.27 | 2.69 | 2.56 | 2.83 | 2.84 |
| 2 | Acid phosphate 200 lbs.
Muriate of potash 25 lbs. | 63.7 | 1.60 | 39.8 | 1.25 | 38.6 | 1.14 | 37.2 | 1.16 | 44.8 | 1.29 | 1615 | 2335 | 960 | 648 | 1890 | 1.23 | 2.06 | 2.49 | 2.74 | 2.13 |
| 3 | No fertilizer ----- | 49.0 | 1.33 | 44.1 | 1.45 | 32.5 | 0.92 | 30.5 | 1.24 | 39.0 | 1.24 | 1255 | 1828 | 980 | 559 | 1156 | 1.09 | 2.12 | 1.67 | 1.65 | 1.63 |
| 4 | Nitrate of soda 100 lbs. | 63.4 | 1.75 | 46.3 | 1.62 | 34.4 | 1.01 | 32.9 | 1.23 | 44.3 | 1.40 | 1064 | 2070 | 907 | 552 | 1148 | .99 | 2.26 | 1.67 | 1.34 | 1.57 |
| 5 | Acid phosphate 200 lbs.
Nitrate of soda 100 lbs. | 56.9 | 1.40 | 54.3 | 1.62 | 37.7 | 0.97 | 37.5 | 1.08 | 46.6 | 1.27 | 1309 | 2530 | 1273 | 784 | 1474 | 1.03 | 3.06 | 2.24 | 2.23 | 2.14 |
| 6 | Muriate of potash 25 lbs.
Nitrate of soda 100 lbs. | 40.3 | 1.25 | 60.0 | 1.30 | 31.9 | 0.93 | 29.3 | 1.52 | 40.4 | 1.25 | 1174 | 2080 | 943 | 960 | 1289 | 0.97 | 2.04 | 1.35 | 1.46 | 1.46 |
| 7 | Acid phosphate 200 lbs.
Muriate of potash 25 lbs.
Nitrate of soda 100 lbs. | 53.4 | 1.55 | 58.5 | 1.70 | 34.9 | 1.04 | 34.1 | 1.59 | 45.2 | 1.47 | 1387 | 1880 | 1122 | 1056 | 1361 | 1.25 | 2.70 | 1.79 | 2.22 | 1.96 |
| 8 | Acid phosphate 400 lbs.
Nitrate of soda 200 lbs. | 38.8 | 1.40 | 50.5 | 1.74 | 39.8 | 1.09 | 37.4 | 1.47 | 41.6 | 1.43 | 1358 | 2250 | 1281 | 880 | 1442 | .97 | 3.02 | 2.08 | 2.51 | 2.15 |
| 9 | Acid phosphate 400 lbs.
Muriate of potash 25 lbs.
Nitrate of soda 200 lbs. | 43.1 | 1.60 | 50.0 | 1.40 | 35.1 | 1.05 | 37.0 | 1.50 | 41.3 | 1.39 | 1480 | 2430 | 1543 | 1208 | 1665 | 1.01 | 3.18 | 1.98 | 2.76 | 2.23 |

DISCUSSION OF RESULTS

The response to phosphate was evident not only for all crops but also in every individual plot where a comparison with an unphosphated plot was possible. It gave the most profitable returns for cotton and the least for corn.



WHEAT PLOTS

No phosphate

Phosphate

For each crop there are four plots which received potash and four to which none was applied, but which were otherwise similarly fertilized. Analysis of the data leaves doubt as to the value of an application of potash for any crop. Both the corn and soybean crops yielded, on the average, a little less with than without potash. The clover and grass and the wheat averaged a little more with the potash than without, but in the case of the clover and grass two potash plots showed gains and two showed losses. It is evident, therefore, that the soil exhibited no special need of this element.

The good yields obtained on the unfertilized plots indicate a fair natural supply of nitrogen. The response to nitrating was not positive for any crop, and the use of nitrate on this soil, which is above the average in productivity, is evidently hazardous. On the other hand, a poor soil of the same origin might be nitrated profitably, especially for cotton and truck crops.

LIMING EXPERIMENTS ON RED LAND

The effect of lime was tested by liming lengthwise one-half of each of the five ranges used in the five-year rotation experiments, so as to have a limed and an unlimed half to each plot. In addition an adjoining range was used in the alfalfa experiments reported in Table 5.

The results as summarized in Table 7 show a slight gain from liming for all crops of the five-year rotation, the gain being most pronounced in the case of the clover and grass. Alfalfa, however, was

practically a failure without lime, and is an example of a crop with an extra-high lime requirement.

Liming experiments were made on red land on another part of the farm. Several limed and unlimed plots were seeded to red clover and a like set to alfalfa in the fall of 1919. The hay crops harvested in 1920 were found to average as follows:

| | Red Clover | Alfalfa |
|---------------|-------------|-------------|
| Limed | 2967 pounds | 3300 pounds |
| Unlimed | 3028 pounds | 1960 pounds |

In this series the red clover did not respond to liming, but the response of alfalfa was very marked.

FERTILIZER AND LIMING EXPERIMENTS ON GRAY LAND

The gray land available for experiments was somewhat low and poorly drained. Unfortunately it proved to be a little uneven in productivity, so that the true value of the results obtained is in doubt. The data as they stand in Table 8 indicate the following:

1. That there was no evident response to the application of acid phosphate in the case of corn or soybeans; there was mild response from wheat, and only a slight response from clover and grass.
2. That there was a small but consistent response to potash.
3. That both wheat and hay crops were appreciably increased by nitrating.
4. That the response to liming was sufficiently marked to be of practical importance.

GENERAL CONCLUSIONS

Rutherford county soils for the most part belong to a group which is naturally fertile, but somewhat deficient in phosphoric acid, and not well supplied with lime. Under good methods of livestock farming it is easily possible to maintain a high degree of soil productivity without the aid of commercial fertilizers other than the moderate use of a plain phosphate, such as acid phosphate. Under one-sided cropping in corn and cotton, with little return of manure, a deficiency not only of phosphoric acid but also of nitrogen and lime becomes increasingly evident. The evidence indicates strongly that potash, if required at all, is of subordinate importance and even of doubtful value in farm practice.

Under the conditions outlined, the kind and quantity of fertilizer and the need of liming will be influenced both by the kind of crop and by the previous treatment of the soil. If a soil has been well cared for and produces good crops of red clover, liming is not indicated as profitable or necessary, although it might be necessary for a high-lime-requirement crop, such as alfalfa. On the other hand, lands that are worn and eroded usually need liming in order to produce a satisfactory crop of red clover. The Station's usual recommendation in

such a case is two tons of ground limestone per acre once in five or six years; but lighter and more frequent applications, say a ton every four years, would probably be ample on these soils.

High-priced crops can evidently be fertilized much more heavily than low-priced. This is especially true of Burley tobacco, which makes a high-grade leaf only under conditions of high yield. Present prices of cotton justify the liberal use of fertilizers for this crop. The same may be said of garden or truck crops in general. On the contrary, corn, which is not only low-priced but also not especially responsive to fertilizers, should not receive much fertilizer. The uncertainty of the small grains, both as to price and yield, makes the use of fertilizers other than a light application of, say, 100 pounds per acre of acid phosphate, of doubtful profit, unless clover and grass follow, in which case a rather liberal application of phosphate is advisable, say 200 or 300 pounds of acid phosphate per acre. In this way the small grain, the clover and grass, and the corn or other crop following are all helped.

FERTILIZER FORMULAS AND RECOMMENDATIONS

WHEAT FOLLOWED BY CLOVER AND GRASS

For wheat or other small grain crop to be followed by clover and grass, apply 200 to 300 pounds per acre of high-grade (16 per cent) acid phosphate. The simplest method of application is by means of a grain drill having a fertilizer attachment, with which seeding and fertilizing are done at one operation. Acid phosphate and fertilizer mixtures in general may, however, be scattered broadcast by hand either before or after plowing, much as farmyard manure is applied, and so get well mixed with the soil.

Top-dressing the wheat with manure in the winter or early spring is very favorable both to the wheat and to the getting of a stand of clover and grass.

SOYBEANS AND COWPEAS

For soybeans, cowpeas, and similar legumes, 100 to 200 pounds of acid phosphate per acre may be used to good advantage. Make the application in the row or broadcast, according to the method of seeding.

CORN AND SIMILAR CROPS

Crops such as corn, sorghum, and millet can not be heavily fertilized with profit. They should follow a soil-improving crop which has been well fertilized, such as clover and grass. However, in experiments conducted for several years on poor soils of the Highland Rim, where the average yield without fertilizer was only 15½ bushels per acre, the yield was found to be increased materially by 225 pounds per acre of the following mixture:

1200 pounds of high-grade acid phosphate
100 pounds of muriate of potash
720 pounds of cottonseed meal

This mixture analyzes approximately as follows:

| | |
|---------------------------------|---------------|
| Available phosphoric acid | 10.0 per cent |
| Ammonia | 2.8 per cent |
| Potash | 3.0 per cent |

The application can well be made in the row at planting time.

TOBACCO

Tobacco, especially Burley, requires a fertile soil, and if possible sod land should be selected. Based in part on experiments made elsewhere in the State, a good formula is as follows:

| |
|--------------------------------|
| 300 pounds of acid phosphate |
| 25 pounds of muriate of potash |
| 40 pounds of nitrate of soda |
| 200 pounds of cottonseed meal |

This mixture analyzes approximately as follows:

| | |
|--------------------------------|-------------|
| Available phosphoric acid..... | 6% per cent |
| Ammonia | 4 per cent |
| Potash | 2% per cent |

Five or six hundred pounds of this mixture per acre is a reasonable quantity. Instead of the 200 pounds of cottonseed meal and 40 pounds of nitrate, either 300 pounds of cottonseed meal, or 90 pounds of ammonium sulphate, or 120 pounds of nitrate of soda may be used; but the larger quantities of either nitrate or sulphate tend to lower the quality of the leaf.

Heavy applications may be made, either all broadcast before ridging, or part in the row and the balance broadcast. Light applications are most effective when applied in the row.

TRUCK CROPS

A good formula for tomatoes, Irish potatoes, and other truck crops is as follows:

| |
|--------------------------------|
| 300 pounds of acid phosphate |
| 50 pounds of muriate of potash |
| 400 pounds of cottonseed meal |

This mixture analyzes approximately as follows:

| | |
|---------------------------------|-------------|
| Available phosphoric acid | 7% per cent |
| Ammonia | 4% per cent |
| Potash | 4 per cent |

Instead of 400 pounds of cottonseed meal, either 160 pounds of nitrate of soda, or 125 pounds of ammonium nitrate may be used; but the nitrate is best applied separately as a top-dressing according to the usual rules.

TABLE 7—Effect of liming in experiments with various crops on brownish-red soil—rate of liming, two tons of ground limestone per acre. Experiments on the farm of the Middle Tennessee State Normal, Murfreesboro.
(Four-year period)

| Crop | Year of harvest and yield per acre | | | | | | | | Average annual yield | | Average annual gain from liming |
|----------------------|------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------------------|-----------|---------------------------------|
| | 1920 | | 1921 | | 1922 | | 1923 | | | | |
| | Limed | Unlimed | Limed | Unlimed | Limed | Unlimed | Limed | Unlimed | Limed | Unlimed | |
| Cotton | 1348 lbs. | 1288 lbs. | 2081 lbs. | 2125 lbs. | 1178 lbs. | 1092 lbs. | 812 lbs. | 801 lbs. | 1355 lbs. | 1327 lbs. | 28 lbs. |
| Corn | 53.8 bu. | 46.2 bu. | 47.5 bu. | 47.7 bu. | 38.1 bu. | 37.3 bu. | 34.0 bu. | 33.6 bu. | 42.1 bu. | 41.2 bu. | 0.9 bu. |
| Soybean hay | 2300 lbs. | 2040 lbs. | 5080 lbs. | 4840 lbs. | 3620 lbs. | 3940 lbs. | 4200 lbs. | 4240 lbs. | 3800 lbs. | 3765 lbs. | 35 lbs. |
| Wheat | 8.9 bu. | 9.2 bu. | 19.7 bu. | 17.1 bu. | 12.7 bu. | 11.7 bu. | 11.4 bu. | 14.1 bu. | 13.2 bu. | 13.0 bu. | 0.2 bu. |
| Clover and grass hay | 611 lbs. | 912 lbs. | 1835 lbs. | 1889 lbs. | 7107 lbs. | 6805 lbs. | 4240 lbs. | 3120 lbs. | 3448 lbs. | 3057 lbs. | 391 lbs. |
| Alfalfa | | | 5140 lbs. | 2160 lbs. | 8400 lbs. | 1700 lbs. | 3520 lbs. | 1500 lbs. | 5687 lbs. | 1787 lbs. | 3900 lbs. |

TABLE 8—Fertilizer treatments and yields per acre of the several crops grown in a five-year rotation of corn-cotton, soybeans, wheat, and clover and grass (2 years). Experiments on the farm of the Middle Tennessee State Normal, Murfreesboro—gray soil.

| Series | Fertilizer | CROP | | | | | | | | | |
|--------|--|--------------|---------|-------|---------|-----------------------|---------|---------|------|---------|------|
| | | Soybean hay* | | Wheat | | Clover and grass hay* | | Limed | | Unlimed | |
| | | Limed | Unlimed | Limed | Unlimed | Limed | Unlimed | Bushels | Tons | Bushels | Tons |
| 1 | Acid phosphate
200 lbs. | 2.06 | 1.98 | 11.7 | 13.7 | 1.75 | 1.75 | 24.4 | .80 | 29.6 | .99 |
| 2 | Acid phosphate
Muriate of potash
200 lbs.
25 lbs. | 2.17 | 1.93 | 10.7 | 11.9 | 1.78 | 1.92 | 23.9 | .89 | 33.1 | 1.06 |
| 3 | No fertilizer (avg. 3 check plots) | 2.50 | 1.80 | 11.0 | 8.1 | 2.04 | 1.39 | 29.5 | 1.10 | 22.9 | .76 |
| 4 | Nitrate of soda*
100 lbs. | 2.17 | 1.82 | 16.0 | 11.3 | 2.91 | 2.07 | 33.0 | 1.31 | 23.8 | .93 |
| 5 | Acid phosphate
Nitrate of soda*
200 lbs.
100 lbs. | 2.11 | 2.10 | 18.7 | 17.9 | 2.66 | 2.02 | 32.2 | 1.05 | 31.2 | .93 |
| 6 | Muriate of potash
Nitrate of soda*
25 lbs.
100 lbs. | 2.33 | 1.83 | 15.3 | 14.5 | 2.62 | 2.07 | 34.2 | 1.04 | 31.8 | 1.05 |
| 7 | Acid phosphate
Muriate of potash
Nitrate of soda*
200 lbs.
25 lbs.
100 lbs. | 2.53 | 2.40 | 22.1 | 21.1 | 2.86 | 2.27 | 34.4 | 1.07 | 29.6 | 1.00 |
| 8 | Acid phosphate
Nitrate of soda*
400 lbs.
200 lbs. | 2.39 | 1.26 | 25.4 | 20.6 | 2.89 | 2.17 | 34.2 | 1.04 | 31.1 | .91 |
| 9 | Acid phosphate
Muriate of potash
Nitrate of soda*
400 lbs.
50 lbs.
200 lbs. | 2.73 | 1.65 | 22.1 | 21.1 | 2.96 | 2.16 | 32.3 | 1.22 | 34.5 | 1.09 |
| | Average | 2.33 | 1.87 | 17.1 | 15.6 | 2.50 | 1.98 | 31.5 | 1.06 | 30.3 | .97 |

*No nitrate applied either to soybeans or to clover and grass.

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NEW INSECTICIDES FOR
THE MEXICAN BEAN BEETLE
AND OTHER INSECTS

By
S. MARCOVITCH



Adult of the Mexican bean beetle

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NEW INSECTICIDES FOR THE MEXICAN BEAN BEETLE AND OTHER INSECTS

By

S. MARCOVITCH

INTRODUCTION

When the Mexican bean beetle (*Epilachna corrupta* Muls.) first invaded Tennessee, in 1920 and 1921, it was at once recognized as a pest that would not readily yield to the insecticides then known. The arsenicals acted mainly as repellents, and were both deficient in killing power and injurious to the tender bean foliage. Control of the pest seemed so hopeless to farmers and truckers that large numbers of them have given up bean growing, except for the early crop. Others depend on hand-picking small patches for home use. Many growers and consumers also fear the possibility of poisoning from eating beans sprayed or dusted with arsenicals. Thus several factors have operated to reduce the growing of beans and to double or triple the price of green beans.



Stages of the Mexican bean beetle: Adult (left), Pupa (center), Larva (right)

During the early invasion of this State there was considerable fear that cowpeas and soybeans would be destroyed. Fortunately, the beetle has not shown any great liking for either of these forage crops and will not attack them severely if no garden beans are close by to serve as a breeding place.

In order satisfactorily to solve the problem of bean beetle control in the home garden and for the trucker it was evident that new insecticides were necessary. Experiments were therefore conducted with numerous non-arsenical compounds that gave promise as cheap and efficient insecticides. A special study was made of the fluorine compounds, since the efficiency of sodium fluoride for roaches and chicken lice is well known. Due to its solubility, it is very injurious to plant life. Fortunately, the less soluble fluosilicates of sodium and calcium, as well as cryolite, were found to be highly effective. Mustard gas adsorbed on charcoal also gave good results against the adult beetles. With these materials it is not necessary

for the beetles to eat bean foliage in order to be killed, as is the case with the arsenicals. It is necessary only that they walk over plants dusted with either sodium fluosilicate or charcoal impregnated with mustard gas, so that some of the dry powder clings to the legs and body. These materials induce an irritation which causes the beetles to lick their feet. Thus the poison enters the mouth, and death results within a few hours. When properly used, these chemicals are not injurious to bean foliage.

Not all of the experimental work reported was carried out to a satisfactory conclusion, but publication is considered justifiable in view of the possibility that other investigators will find the suggestions useful.

EXPERIMENTAL WORK WITH INSECTICIDES

CAGE EXPERIMENTS

More than 40 different chemicals and combinations were tested in the course of the work against the Mexican bean beetle. They were first tried out in small wire cages or under glass cylinders. Those that gave promise were given a field trial on a larger scale, a discussion of which is given in the plot experiments. The glass cylinders were inverted over bean plants growing out in the open,



Egg mass of the Mexican bean beetle

and for each material tried out 10 beetles were used. When lime was used as a carrier, the chemicals were measured out by volume because of their high density. Observations were made twice a day as to the rapidity with which the materials killed. Records were kept of the date the first beetles died, and the time required to kill all of the 10. Foliage injury was recorded as "severe" if all of the leaves were badly injured, "medium" if one or two leaves were injured, and "slight" if injury occurred only at the tips or edges of the leaves and could hardly be detected. Some of these chemicals that were injurious to bean foliage were not detrimental to cotton plants.

TABLE 1—*Test of insecticides used as dusts against the Mexican bean beetle under cages—ten beetles used under each cage*

| Material or compound | Date of application | Date first beetles died | Date last beetles died | Injury to bean plant | Notes |
|--|---------------------|-------------------------|------------------------|----------------------|---|
| Sodium fluoride (NaF)..... | May 1 | May 2 | May 3 | Severe | |
| Calcium fluoride (CaF ₂)..... | May 1 | May 24 | May 30 | None | |
| Sodium fluosilicate (Na ₂ SiF ₆) | May 1 | May 2 | May 3 | Slight | |
| Sodium fluosilicate plus 9 parts lime | June 5 | June 6 | June 9 | None | |
| Natural cryolite (Al ₂ F ₆ .6NaF) | June 6 | June 7 | June 7 | None | |
| Natural cryolite plus 5 parts lime | June 7 | June 8 | June 8 | Severe | |
| Synthetic cryolite | June 26 | June 27 | June 28 | None | |
| Silica (SiO ₂)—by-product Knoxville Fertilizer Company | June 7 | June 8 | June 9 | None | Contains a small amount of fluorine compounds |
| Calcium arsenate plus 9 parts lime | June 6 | June 8 | June 10 | None | |
| Crude anthracene | June 6 | June 7 | June 7 | Severe | |
| Calcium fluosilicate (CaSiF ₆) | July 22 | July 22 | July 22 | Severe | All beetles dead in 6 hours |
| Calcium fluosilicate plus 9 parts lime | Aug. 12 | Aug. 13 | Aug. 14 | None | |
| Magnesium fluosilicate (MgSiF ₆) | July 22 | July 22 | July 24 | Severe | |
| Charcoal plus 10% nitrobenzene | July 10 | July 11 | July 12 | None | |
| Charcoal plus 10% creosote | July 10 | July 11 | July 12 | Severe | |
| Charcoal plus 10% kerosene | July 21 | July 22 | July 22 | None | |
| Charcoal plus .6% mustard gas | July 22 | July 22 | July 23 | None | All but one dead in 4 hours |
| Charcoal plus .01% mustard gas | Aug. 20 | Aug. 20 | Aug. 21 | None | All but one dead in 6 hours |
| Charcoal plus 2% nitrobenzene and .5% mustard gas | Sept. 8 | Sept. 8 | Sept. 10 | None | All but one dead in 4 hours |

Table 1 gives the results of the more important chemicals tested as dusts against the adults of the Mexican bean beetle. The soluble fluorides, such as sodium fluoride, and the soluble magnesium fluo-



Bean leaf, showing work of the Mexican bean beetle

silicate, were effective in killing the beetles, but were injurious to the bean foliage. Fluorspar, an insoluble fluoride, did not kill rapidly enough to be of value. The insoluble cryolite, however, gave excellent results, as it is easily decomposed by the acids within the alimentary canal of the insect. This material is also easily decomposed by alkalis, such as hydrated lime, which when mixed with cryolite in certain proportions resulted in injury to the plant.

The slightly soluble fluosilicates of sodium and calcium were very efficient in destroying the beetles. Sodium fluosilicate even when used pure, showed very little injury to the foliage. When mixed with hydrated lime its killing efficiency was not greatly reduced. Calcium fluosilicate, although comparatively insoluble, showed severe injury to the foliage, due to the fact that it hydrolyzes. The injurious effect, however, disappeared when it was mixed with hydrated lime.

Certain very toxic organic compounds when adsorbed on charcoal were also effective in destroying the beetles, and did not injure the bean foliage. A discussion of these will be taken up more fully in another section.

SODIUM FLUOSILICATE

Control of other insects.—Experiments were conducted with

sodium fluosilicate against cockroaches and poultry lice, for which sodium fluoride is commonly recommended. It was found effective against roaches, and superior to sodium fluoride for poultry lice. Mr. Zuger, of the poultry department of the University, who conducted most of the tests, observed that after an application of sodium fluosilicate, chickens remained free of lice for a much longer period than when dusted with sodium fluoride. He also found that the wing louse (*Lipeurus variabilis*) was more effectively controlled by sodium fluosilicate.

Tests conducted against the potato beetle (*Leptinotarsa decemlineata*), the potato flea-beetle (*Epirix cucumeris*), the bean leaf-beetle (*Ceratoma trifurcata*), the cucumber beetle (*Diabrotica vittata*), and the tobacco hornworm (*Protoparce quinquemaculata*) showed that they could be readily killed with sodium fluosilicate when 1 part was mixed with 9 volumes of lime. When undiluted with lime it caused some injury to the plants, particularly in the case of tobacco.

Since sodium fluosilicate is both a contact and a stomach poison, it should, theoretically, be effective against the boll weevil (*Anthonomus grandis*), and such was found to be the case. Cotton is a comparatively resistant plant, and is not injured when sodium fluosilicate is used undiluted. In all the tests conducted, the weevils were killed in from 5 to 24 hours. Calcium arsenate under similar conditions required from 1 to 5 days to kill the weevils. It was also observed that they could be killed in the same length of time by contact alone. To make sure that they were killed by contact, some weevils were placed on a bean plant, which they do not eat. After the weevils had crawled over the bean plant, which had been dusted with sodium fluosilicate, 50 per cent were dead in 6 hours, and the rest were found dead the next morning.

Advantages over the arsenicals.—Sodium fluosilicate is superior to the arsenicals in several different ways. In the first place, it is cheaper; the wholesale price being 4 cents per pound at the present time, while calcium arsenate is quoted at 9 cents per pound, and magnesium arsenate at 25 cents per pound.

Secondly, it is both a contact and a stomach poison, and acts more rapidly than the arsenicals.

Shafer, in his classical work "How Contact Insecticides Kill,"* has shown how sodium fluoride is effective against roaches. In much the same way sodium fluosilicate is effective against the bean beetles. When a roach runs through powdered sodium fluoride, a little of the powder adheres to the lower part of the body, antennae, and feet. In attempting to clean itself the insect draws its feet and antennae across its mouth. Some of the material thus enters the mouth, and causes death in from 4 to 12 hours. Shafer observed

*Mich. Agr. Exp. Station Tech Bull. No. 21.

that sodium fluoride may kill roaches by contact in from 5 to 22 hours, even when none of the material is swallowed. "Some of the powder is moistened or dissolved in the exudation about the bases of the legs and on the thinner portions of the outer integument. This seems to cause some irritation and uneasiness; the insect soon begins to clean the moistened powder from the body by licking it. In doing this, enough of the poison may be brought into the mouth, and swallowed, to kill after a period varying from five hours to ten days." Sodium fluoride is more rapid as a stomach poison than as a contact insecticide, and appears to be detrimental to certain enzymes, particularly the catalases. Fortunately, bean beetles, in common with roaches and certain other insects, have the habit of cleaning themselves by putting their feet into their mouths, and hence are easily killed.

Thirdly, sodium fluosilicate is considered less dangerous to man. This is a distinct advantage, for in spite of the improbability of human poisoning from beans which have been dusted with calcium arsenate, the prejudice is so great that many farmers refrain from applying arsenicals to beans. On the other hand, sodium fluosilicate in small quantities is non-poisonous to man, and for that reason should be more popular than the arsenates for dusting beans. It should not be assumed, however, that there is no danger whatever and the material used carelessly. Recently a case was reported of fatal poisoning* from the eating of bread the flour of which had been accidentally mixed with sodium fluosilicate.

Another advantage of sodium fluosilicate is its efficiency against widely separated insects, such as chicken lice, cockroaches, and potato beetles.

Disadvantages.—As obtained on the market today, sodium fluosilicate is two or three times as "heavy" as calcium arsenate. A pound of the latter will occupy 80 cubic inches, and will cover a larger surface than sodium fluosilicate. In the manufacture of calcium arsenate, however, considerable experimental work was necessary in order to obtain a light, fluffy material. A few preliminary experiments showed that sodium carbonate when added to hydrofluosilicic acid gives a precipitate the density of which is less than when sodium chloride is used. Sodium silicate added to hydrofluoric acid also gave a "light" precipitate, which showed properties analogous to those of sodium fluosilicate. It is probable that further research will solve this factor of density, and that a lighter sodium fluosilicate can be obtained.

Sodium fluosilicate can not be used as a liquid spray on beans because in this form it is more or less injurious to the tender bean

*Bull. Sci. Pharmacol. Vol. 30: 211. 1923.

foliage. Used as dust and mixed with hydrated lime it appears to cause no injury.

Source and uses.—Sodium fluosilicate occurs as a by-product in the manufacture of acid phosphate. When phosphate rock and sulphuric acid are mixed, hydrofluosilicic acid is produced. Upon the addition of common salt, sodium fluosilicate is precipitated. This is used in the ceramic industries and in enamel factories for the manufacture of glass and tile. It is also used as an antiseptic and germicide, and is considered superior to either the fluorides or corrosive sublimate in certain medical practices. It is soluble to the extent of 1 part to 200 parts of water.

CALCIUM FLUOSILICATE

Good results having been obtained with sodium fluosilicate, other fluorine compounds, such as calcium fluosilicate (CaSiF_6), were tested. This material is not at the present time produced in large quantities, so that an excessive price has to be paid for a small amount to be used experimentally. The pure calcium fluosilicate was found extremely toxic to the bean beetles, requiring but a few hours to kill them; but the plants were severely injured.

An attempt was made to make a small amount in the laboratory by adding an excess of milk of lime to hydrofluosilicic acid. The precipitate obtained did not injure the plant and did not kill as rapidly as the pure calcium fluosilicate, due possibly to the formation of inactive substances, such as calcium fluoride. When ground calcium carbonate was substituted for the lime, the resulting product showed practically as much killing power as the pure calcium fluosilicate, with but slight injury to the plant. Further research is needed to determine the action of the oxides and carbonates of calcium with hydrofluosilicic acid.

CRYOLITE

Samples of the powdered native mineral ($\text{Al}_2\text{F}_6 \cdot 6\text{NaF}$) were obtained and dusted on bean plants under cages. It was found very efficient, killing bean beetles in from 10 to 20 hours. It very likely breaks up when ingested by the insects and forms toxic products. Fluorspar, on the other hand, is much more stable and therefore much less toxic.

Mixed with 5 parts of hydrated lime, cryolite killed the beetles but also injured the bean plant. It was very evident that cryolite reacts with hydrated lime, even when used as a dust. The chemistry of cryolite-lime mixtures will not be taken up at this time, but it is certain that various toxic fluorides, aluminates, and hydroxides are formed. When cryolite was mixed with two parts of lime, the beetles were dead after 2 days, and the plant was not

injured. A spray containing 2 pounds of cryolite and 4 pounds of lime to 50 gallons of water was found effective in killing the beetles within 2 days.

Cryolite is also made synthetically from bauxite. The following analysis was claimed for a sample quoted at 8 cents per pound:

| | |
|---------------------------|----------------|
| Aluminum fluoride | 45.70 per cent |
| Sodium fluoride | 42.60 per cent |
| Sodium fluosilicate | 11.50 per cent |
| Iron oxide | .18 per cent |

Cryolite is a white, glassy, crystalline solid, soluble in 2730 parts of water. It is found in large quantities in Southern Greenland, which exports thousands of tons annually, and is used in the manufacture of aluminum, alum, and various fluorides.

SILICA BY-PRODUCT

As mentioned previously, hydrofluosilicic acid is a by-product from the manufacture of acid phosphate. Formerly the by-product gases were allowed to pass into the atmosphere. Since even a very small percentage of fluorine gas in the air is highly injurious to plant life, many complaints were made by growers in the neighborhood of fertilizer factories. To overcome this difficulty, the gases are now passed into towers with dripping water, forming hydrofluosilicic acid and a precipitate of silica. A sample of such by-product silica gave fair results in killing adults of the Mexican bean beetle. It is obvious, since pure silica is not an insecticide, that some impurities, such as adsorbed fluorine compounds, are the active insecticidal ingredients. One other sample of silica, obtained from an entirely different source, also showed some insecticidal properties.

ADSORBED GASES

The value of an insecticide is determined to a large extent by its physical state, it being most efficient in the form of a gas. The gases used in the late war have been tried out as poisons in various ways by many investigators,* with satisfactory results for stored-product and other insects. In the field, however, marked injury to the plants takes place when gases are used as in fumigating.

To obviate injury to the leaves, the writer conceived the idea of using charcoal impregnated with adsorbed gases which would be liberated gradually. Thus not enough gas would be present to injure the plant, while it would kill those insects which crawled over the material.

*McDonnell, C. C. "Recent progress in insecticides and fungicides." *Ind. and Eng. Chem.*, 16: 1018. 1924.

The results were gratifying, indeed, particularly with respect to the Mexican bean beetle. Mr. C. W. Exton, of the Chemical Warfare Service, supplied samples of activated and unactivated charcoal with various percentages of mustard gas (dichlorethysulfide (ClCH_2CH_2)₂S). This compound is a colorless, oily liquid, with a boiling point of 215°-217°C. Of all the war gases, it is one of the most toxic. It should be used with caution, since it has an irritating effect on the skin, upon prolonged exposure, in as low a concentration as 1 to 5,000,000. Amounts as small as .01 per cent of mustard gas on charcoal with a little ether proved effective in killing bean beetles in from 3 to 6 hours. When a beetle crawls over a plant dusted with impregnated charcoal, it soon becomes uneasy, tries to fly away, and starts to clean its feet. By this last operation the beetle no doubt gets some of the gases into its mouth, and death ensues within a few hours. One-tenth per cent, .6 per cent and 2 per cent nitrobenzene with .5 per cent mustard gas, without ether, proved no more effective than the .01 per cent mustard gas. Neither plant injury nor discomfort to the operator was caused by mustard gas in either of the several concentrations used.

Beetles succumbed the day after being placed on a plant that had been dusted with .01 per cent mustard gas 18 days previously, showing that the gases are active in the charcoal for several weeks.

With other insects, impregnated charcoal gave varying results. Small tobacco hornworms were killed by .01 per cent mustard gas, but the large ones were not affected.

No field trials were made with the mustard gas, but one plot was dusted with wood charcoal which had been mixed with about 5 per cent liquid nitrobenzene. Good control was obtained by four weekly applications. Examination among the plants also revealed dead beetles.

Adsorbed gases were also tried against the boll weevil. In general, the results were the same as those secured against the bean beetle, but less effective control was obtained. The smaller percentages of mustard gas, such as .01 per cent, gave better control than the larger percentages, probably because the small amounts also contained ether. In many cases weevils succumbed in 4 hours after crawling over charcoal impregnated with .01 per cent mustard gas and a little ether. Others became torpid and died in from 1 to 5 days. Sixteen per cent mustard gas, by weight, did not injure the cotton plant. When a weevil crawls over impregnated charcoal it begins to rub its legs and tries to fly. After making several attempts at flying, it becomes weakened and unable to fold its wings beneath the wing covers. Wood charcoal can be obtained on the market today at less than \$2.00 per 100 pounds. The cost

of impregnated charcoal should not be great when made on a large scale. It is possible that with further investigation a combination will be found that will make an effective insecticide.

PLOT EXPERIMENTS

More than twenty 1/40-acre plots were used to determine the value of the more promising insecticides, as well as those in common use. The experiments were carried out at the Experiment Station farm at Knoxville and duplicated at Crossville, on the Cumberland Plateau. The following 21 varieties of beans were tested to de-



Rotary dust gun, showing manner of turning nozzle sideways to direct dust to underside of leaves

termine any possible natural resistance to bean-beetle attack: Burpee's Brittle Wax, Hodson Wax, Rustproof Golden Wax, Burpee's Stringless Green Pod, Giant Stringless Green Pod, Extra Early Red Valentine, Black Valentine, Tennessee Green Pod, Refugee, Robust Pea Bean, Red Kidney, Kentucky Wonder, Scarlet Runner, Horticultural, Philadelphia Bush Lima, Burpee's Improved Bush Lima, Henderson's Improved Bush Lima, Burpee's Sunny Brook, Pole Lima, King of the Garden, Carolina, and Jackson Wonder. None was found resistant, although in general the lima beans are less attractive to the beetles, and when close to garden beans will make a crop with little or no dusting. The details of all the plot experiments are not given below. Only those are given which are representative and bring out the points desired.

SODIUM FLUOSILICATE PLUS 9 PARTS OF LIME

Plot 1.—This plot was planted on April 8 to Early Red Valentine. The beans came up April 22, and the beetles began to make



Plot 1, where sodium fluosilicate mixture was used, showing perfect protection



Plot 2, untreated—destroyed by Mexican bean beetle

their appearance May 21. The bean leaf-beetle (*Cerotoma trifurcata*) was unusually abundant, so that an application of sodium fluosilicate plus 9 parts, by volume, of lime was made May 22. The next day dead adult bean leaf beetles were very abundant on the

ground among the bean plants. The application was made with a hand-bellows duster just after the dew had disappeared. Twenty minutes were required to apply one pint ($\frac{1}{2}$ lb.) of the mixture to the plot 18 by 60 feet. Because of rain, the application was repeated May 30, and again June 4. Previous to the latter application, 7 beetles to a row were counted. Two subsequent applications were given June 14 and June 19. These last applications were made with a rotary dust gun, the nozzle being turned sideways so as to direct the dust to the underside of the leaves, as shown in the illustration.

At no time was the patch seriously threatened, as the applications were made when the beetles were noticed and before egg-laying was under way. The mixture appeared to act as a repellent and a poison, for a reduction in the number of beetles was observed the day following an application. On June 10, 6 dead beetles were found under the vines of one row. On June 14 a few small larvae were observed in the plot. At no time was the larval infestation as much as one per cent. Complete protection was obtained, whereas the check plot was very seriously infested by June 26 (page 13).

TABLE 2—Cost of sodium fluosilicate* treatments for the control of the Mexican bean beetle, and calculated money returns

| Plot No. | Date of application | Quantity of material per acre | Cost of materials | Time making applications | Cost of labor | Total cost per application | Yield per acre | Value | Total cost of dusting | Net returns from treatment |
|-----------|---------------------|-------------------------------|-------------------|--------------------------|---------------|----------------------------|----------------|----------|-----------------------|----------------------------|
| | | Lbs. | | Hrs. | | | Bu. | | | |
| 1 | May 22 | 20 | \$.50 | 8 | \$1.60 | \$2.10 | 104 | \$260.00 | \$9.90 | \$187.60 |
| | May 30 | 20 | .50 | 8 | 1.60 | 2.10 | _____ | _____ | _____ | _____ |
| | June 4 | 20 | .50 | 6 | 1.20 | 1.70 | _____ | _____ | _____ | _____ |
| | June 14 | 30 | .80 | 6 | 1.20 | 2.00 | _____ | _____ | _____ | _____ |
| | June 19 | 30 | .80 | 6 | 1.20 | 2.00 | _____ | _____ | _____ | _____ |
| Untreated | | | | | | | 25 | \$ 62.50 | | |

*1 part plus 9 parts hydrated lime.

The amounts of materials used and the time consumed in making applications are given in Table 2. The dusted plot yielded at the rate of 104 bushels per acre, while the check plot yielded 25 bushels. The market price of green beans was from two to three dollars per bushel. At \$2.50 per bushel the dusted plot would have returned \$260 per acre. The total cost of the five applications was \$9.90, giving a net return increase due to dusting of \$187.60 per acre. This large net return was obtained on $\frac{1}{40}$ of an acre, and indicates what is possible with a heavy bean beetle infestation, and the high prices which result when the pest is left uncontrolled.

Plot 9.—The effect of sodium fluosilicate with 9 parts, by volume, of lime was given a trial later in the summer, when the beetles were very abundant. Tennessee Green Pod and Black Valentine varieties were planted July 1. Half of the plot was left untreated and the remaining half was dusted July 17, 21, and 25, and August 5 and 9. Just before the first application there were about 50 beetles to the row. Eggs were also present. The next day a count revealed only 4 beetles to the row on the dusted half and 30 to the row on the untreated half. On July 21, the beetles were extremely numerous—80 to the row—on the untreated portion. On August 7, full-grown larvae were present on the check plot, and by August 12 the patch was completely infested. On the other hand, good protection was obtained in the treated portion of the plot as long as the plants were kept covered with dust. After



Treated with sodium-fluosilicate-
lime mixture

Untreated

the crop was made, the beetles multiplied so rapidly in the untreated half that they attacked the treated half, as it was no longer being protected. By September 3 both halves were destroyed.

SODIUM FLUOSILICATE PLUS 15 PARTS OF LIME

Plot 8.—To determine whether sodium fluosilicate could be diluted still more, it was mixed with 15 parts, by volume, of lime. In this plot Tennessee Green Pod was planted May 6. Applications were made June 4, 10, 14, and 19. The protection obtained was not so good as with the mixture of one to nine, yet the infestation was reduced to 30 per cent. Two and one-half bushels of beans were obtained from this plot.

CALCIUM ARSENATE PLUS 9 PARTS OF LIME

Plot 4-A.—To compare the results of the new chemicals tested with those of the present methods, several plots were used. The plot treated with calcium arsenate plus 9 parts of lime was planted to Black Valentine May 6. Applications were made June 5, 10, 14, and 19, and on June 25 infestation was only 10 per cent.

The Crossville plots treated with calcium arsenate plus 9 parts of lime developed a 20 per cent larval infestation. Five applications were made, June 17 and 25 and July 3, 8, and 23.

MAGNESIUM ARSENATE

Plots 3 and 5.—Recently N. F. Howard, of the United States Bureau of Entomology, has obtained good results with magnesium arsenate as a wet spray, using 1 pound to 50 gallons of water. This material was tested on plot 3, planted May 6 to Burpee's Improved Bush Lima, and plot 5, to pole beans, such as Kentucky Wonder, Carolina, or Sieva, and Sunny Brook Pole Lima. Applications were made June 5, 10, 14, and 19 to both plots.

Plot 3 remained free of larvae and beetles as long as the spraying was continued. As no applications were made after June 19, the beetles subsequently became numerous, so that by August 7 there was a 100 per cent infestation. The bean yield was not materially reduced, however, for the earlier protection had enabled the plants to develop a good crop.

The pole beans received an additional application July 17. The infestation never exceeded 1 per cent, and an excellent crop of beans was secured. Howard* does not recommend the growing of pole beans where the beetles are numerous, but this experiment indicates that pole beans can be grown in Tennessee, even though the pods are matured slowly and are produced over an extended period of time.

Plots were also planted to bush beans in late summer and sprayed with magnesium arsenate 5 times. Adequate protection was again obtained, the results of the treatments being aided by hot, dry weather.

CAL-SULPHUR

Plot 4.—One part of calcium arsenate and 1 part of sulphur to 4 parts of lime was used on plot 4 at Knoxville, planted to Tennessee Green Pod May 6. The first application was made June 4. On June 3 the beetles were very numerous, averaging 65 to the row. Subsequent applications were made June 10, 14, and 19, and on June 25 less than 5 per cent infestation was observed. By June 27 a yield at the rate of 110 bushels per acre had been obtained. "Cal-sulphur" also gave good control at Crossville.

*Bull. 1243, U. S. Dept. Agr., p. 49. 1924.

DISCUSSION OF THE PRACTICAL CONTROL OF THE MEXICAN BEAN BEETLE

One reason why many gardeners fail to keep the Mexican bean beetle in check is that the familiar principles of control for the potato beetle are applied to the bean beetle. The rule followed in the control of the potato beetle is to apply an arsenical when the grubs are conspicuous. Since the young of the potato beetle eat the entire leaf, they can be very easily poisoned. With the bean beetle, however, feeding takes place almost altogether on the underside of the leaf, so that poison applied in the ordinary manner fails to kill them. Furthermore, when the spray or dust is applied to the underside of the leaves, it is difficult to coat them evenly and thoroughly, and many of the larvae escape.

In our experiments it was found to be much easier to drive away or to kill the active adult beetles than to kill the larvae, particularly when sodium fluosilicate was used as a dust. It was observed that the beetles are very sensitive to any dust on the plants, such as lime or wood ashes, and can be literally "scared" out of a patch when it is kept thoroughly covered with such materials. For this reason, much better success can be had if control measures are directed against the adult beetles when they first make their appearance. The remark is sometimes heard that the bean beetle is not as bad as it was two or three years ago. Investigation usually shows that some material such as wood ashes, lime, road dust, or some such material, is being applied. Much better control would be obtained, however, if sodium fluosilicate were mixed with hydrated lime.

RECOMMENDATIONS FOR THE CONTROL OF THE MEXICAN BEAN BEETLE

DUSTS

When the beetles appear, apply immediately a dust mixture of sodium fluosilicate plus 9 parts, by volume, of hydrated lime, at the rate of 15 to 25 pounds of the mixture per acre, depending on size of plants and degree of infestation. Care should be exercised to obtain as light a sodium fluosilicate as possible, as some firms are putting out a heavy product. If sodium fluosilicate cannot be obtained, a dust of calcium arsenate plus 9 parts of lime, or a dust consisting of 1 part of calcium arsenate, 1 part of fine dusting sulphur, and 4 parts of hydrated lime may be used.

Care should be exercised to apply the materials to the underside of the leaves, as shown in the illustration on page 12. From 15 to 25 pounds of the mixture, consisting of 1 part of sodium fluosilicate and 9 parts, by volume, of lime, should be used per acre, the quantity depending on the size of the plants and the severity of the infestation. For small patches and

gardens a hand-bellows duster is satisfactory. For larger fields, the rotary dust gun or knapsack-bellows duster will cover the ground in shorter time.

Good results may be obtained with the rotary fan duster by turning the nozzle sideways and blowing the dust to the underside of the leaves, as shown in the illustration. Where the infestation is heavy the nozzle may be directed vertically over the bean plants and dragged along over the tops in such a manner as to turn the leaves over. In this way the dust may be applied to the underside of the top leaves, where the adults frequently feed.

The first dust applications should be made as soon as the beetles appear in the patch and before egg-laying is under way. Ordinarily the second application is given in about a week. If no rains occur and the beetles are not numerous, the second application may be delayed 10 days or more. If rains wash the materials off and the beetles are abundant, it is advisable to dust again four or five days after the first application. Where beetles are not numerous, one or two applications may suffice. Usually three or four will be necessary, a week or ten days apart, until the crop is about made. For pole beans and other late varieties, five or six applications may be necessary.

SPRAYS

Although dusts are becoming more popular, because of ease of handling and rapidity of application, good results in the control of the bean beetle may be had with liquid sprays, such as magnesium arsenate, applied at the rate of 2 pounds to 100 gallons of water, to the underside of the leaves. For pole beans, a liquid spray has the advantage of not forming a cloud of dust at the level of the nose of the operator.

When calcium arsenate is to be used as a spray it is advisable* to make the mixture in the following proportions:

| | | |
|------------------------|-----|----------|
| Hydrated lime | 3 | lbs. |
| Calcium arsenate | 1½ | lbs. |
| Water | 100 | gallons. |

The lime is used to prevent "burning." Arsenate of lead is considered unsafe to use on bean foliage.

*Farmers' Bull. 1407, U. S. Dept. of Agr. 1924.

SUMMARY

1. The experimental work showed that many of the fluorine compounds were effective in destroying the adult Mexican bean beetles. Sodium fluosilicate, calcium fluosilicate, and cryolite have considerable insecticidal value when mixed with hydrated lime in the proper proportions.

2. Sodium fluosilicate is a contact as well as a stomach poison. Because of its irritating effect, the beetle attempts to clean its feet in its mouth. Enough of the chemical thus enters the mouth to cause death.

3. Sodium fluosilicate has these advantages over the arsenicals: (1) It is cheaper, (2) it acts as a contact as well as a stomach poison, (3) it kills more rapidly, (4) it is less poisonous to people, and (5) it is effective against a variety of insects, such as chicken lice, roaches, tobacco hornworms, flea-beetles, and potato beetles.

4. The density of sodium fluosilicate, as obtained in the market to-day, is high, but work is being carried out to remedy this defect.

5. Cotton boll weevils were killed with sodium fluosilicate without lime in from 4 to 30 hours.

6. Gases adsorbed on charcoal gave good results as insecticides. Charcoal containing .01 per cent mustard gas with a little ether was dusted on plants, and bean beetles were killed in from 3 to 12 hours. Nitrobenzene on charcoal was also effective in destroying the beetles.

7. The above gases killed boll weevils in from 6 hours to 5 days.

8. When used as a dust, sodium fluosilicate mixed with 9 parts, by volume, of hydrated lime gave excellent control in the field against the bean beetle.

9. When mixed with 9 parts of hydrated lime, and properly used, sodium fluosilicate showed a net return as high as \$187.60 per acre, at a time of the season when the bean beetles were very abundant.

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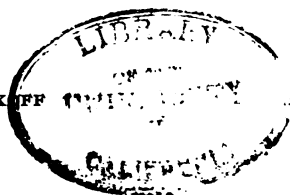
BULLETIN No. 132

MARCH, 1925

SPRAYING EARLY APPLES FOR
BLOTCH CONTROL

By

J. A. MCCLINTOCK AND C. D. SHERBAKOFF



TWO BLOTCHED EARLY HARVEST APPLES

The majority of the early apples in commercial orchards looked like this at the time the spray experiments were started.

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The Agricultural Building, containing the offices and laboratories of the Experiment Station, the College class rooms, and the headquarters of the Division of Extension, is located at the University Farm, on Kingston Pike, about one mile west of the main campus. Farmers are cordially invited to visit the building and the experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

SPRAYING EARLY APPLES FOR BLOTCH CONTROL

BY

J. A. McCLINTOCK AND C. D. SHERBAKOFF

INTRODUCTION

Various apple diseases, such as blotch, bitter-rot, scab, and black-rot, are present in orchards throughout Tennessee. Their importance is not fully realized, however, until the growers attempt to produce apples for commercial shipment, the fruit attacked by these diseases being unsuitable for this purpose.

Commercial growers have been following for many years the spray schedule recommended for this State, but the results have been varied, and often quite poor. In the spring of 1923 spray tests were undertaken to determine whether the poor results were due to an incorrect spray schedule, or to a lack of thoroughness in applying the sprays. These tests were located in four commercial orchards of Williamson and Maury Counties, in the heart of the Middle Tennessee early-apple section. They were conducted co-operatively by H. B. Holcombe, W. I. Smith, and S. G. Abernathy, of the Agricultural Extension Service of the University of Tennessee, and C. D. Sherbakoff and J. A. McClintock, of the Experiment Station.

In 1923 the commercial growers in whose orchards the test plants were located followed the approved University spray schedule compiled by N. D. Peacock, of the College of Agriculture, and published as Extension Publication No. 113. The schedule for apples contained in that publication is given on page 4 of this bulletin.

In the test blocks a special schedule was followed which differed from the regular one in that Bordeaux mixture 3-4-50 was used in the place of lime-sulphur for the calyx spray. It also varied in the time of the subsequent applications, which were made one week earlier than called for in the approved schedule.

EXPERIMENTAL RESULTS

Season of 1923

In each case the special spray schedule was used on square blocks of 16 trees, while the trees outside these test blocks* were sprayed according to the schedule referred to. In the tests the first, or calyx, spray was applied between April 27 and May 1. It soon became evident that the spraying of the test blocks was much more thorough than that of the rest of the trees in the orchards. That

APPLE SPRAY SCHEDULE

| Insects and diseases to be controlled | Materials to be used | Time of application |
|---------------------------------------|--|--|
| San Jose scale | Lime-sulphur, 5 degrees Baume (commercial liquid material, diluted 1-7). | Dormant season—
Early winter, before February 1st. |
| Scab | Lime-sulphur, 1 degree Baume. | Pink-bud— |
| Black-rot on leaves | 40% nicotine sulphate (Black-leaf 40), $\frac{1}{2}$ pint to 50 gals. | As the individual buds in a cluster begin to separate. |
| Apple aphid | Arsenate of lead, 1 pound to 50 gallons. | |
| Curculio | Lime-sulphur, 1 degree Baume. | Petal-fall or calyx spray—
Begin when petals are $\frac{1}{4}$ off and finish before the calyx closes. |
| Scab | Arsenate of lead, 1 pound to 50 gallons. | |
| Black-rot on leaves | | |
| Codling moth | | |
| Curculio | Bordeaux mixture 3-4-50. | Two-weeks spray—
Begin 10 days following last spray and finish by 2 $\frac{1}{2}$ weeks after petal-fall. |
| Blotch | Arsenate of lead, 1 pound to 50 gallons. | |
| Scab | | |
| Codling moth | | |
| Curculio | Bordeaux mixture 4-5-50. | Five-weeks spray—
Begin two weeks after previous spray, finish by five weeks after petal-fall. |
| Blotch | Arsenate of lead, 1 pound to 50 gallons. | |
| Bitter-rot | | |
| Black-rot on fruit | | |
| Scab | | |
| All leaf-eating insects | Bordeaux mixture 4-5-50. | Seven-weeks spray—
Begin two weeks after last spray. |
| Bitter-rot | | |
| Blotch | | |
| Scab | | |
| Black-rot on fruit | | |
| Codling moth, 2nd brood | | |
| Bitter-rot | | |
| Blotch | | |
| Black-rot on fruit | | |
| Scab | | |
| Sooty-blotch | | |
| Leaf-eating insects | Bordeaux mixture 4-5-50. | Late-season sprays—
Repeat as needed (especially in hot weather), until two weeks before harvest. |

In each case the powdered form of arsenate of lead is referred to in the above schedule.

is, the twigs, leaves, and young fruits in the test blocks were completely covered with spray material, while those outside the test blocks showed from 10 to 50 per cent of the surfaces unprotected by spray material. This was also observed in subsequent applications throughout the season. This difference in thoroughness was due to the growers' spraying the trees outside the test blocks as they had been accustomed to spraying, while the test trees were carefully sprayed under expert supervision from the Experiment Station.

In order that definite data might be obtained on the relative effectiveness of the two spray schedules as regards freedom of the fruit from disease, from 5 to 15 bushels of fruit in each case was taken from trees both within and without the test blocks. As the data show important differences only in the amount of healthy and of blotched fruit, the individual figures for the other diseases, and for the insect injuries, are omitted from consideration.

The figures in Table 1 do not tell the whole story, because in the test blocks all fruits which showed signs of blotch were recorded as diseased even though the infection was so slight that the fruit graded No. 1, while on many of the blotched fruits from the rest of the orchard the infection was so serious that the apples were graded as culls. The figures show a great difference, however, in favor of the test spraying—the average for the four demonstrations being 63 per cent more healthy fruit and 63 per cent less blotched fruit from the test blocks than from the trees outside the test blocks.

TABLE 1—Results of 1923 spray tests with Early Harvest apples

| Orchard No. | Trees outside demonstration blocks | | | Trees in demonstration blocks | | |
|-------------|------------------------------------|----------|------------------------------------|-------------------------------|----------|------------------------------------|
| | Healthy | Blotched | Other diseases and insect injuries | Healthy | Blotched | Other diseases and insect injuries |
| | % | % | % | % | % | % |
| 1 | 8 | 90 | 2 | No demonstration test | | |
| 2 | 49 | 44 | 7 | 90 | 7 | 3 |
| 3 | 33 | 64 | 3 | 93 | 5 | 2 |
| 4 | 29 | 69 | 2 | 97 | 1 | 2 |
| Average | 30 | 67 | 3 | 93 | 4 | 2 |

TABLE 2—Results of 1924 spray tests with Early Harvest, Duchess, and Yellow Transparent apples

| Orchard No. | EARLY HARVEST | | | | | | DUCHESS | | | | | | YELLOW TRANSPARENT | | | | | |
|-------------|------------------------------------|----------|------------------------------------|-------------------------------|----------|------------------------------------|------------------------------------|----------|------------------------------------|-------------------------------|----------|------------------------------------|------------------------------------|----------|------------------------------------|-------------------------------|----------|------------------------------------|
| | Trees outside demonstration blocks | | | Trees in demonstration blocks | | | Trees outside demonstration blocks | | | Trees in demonstration blocks | | | Trees outside demonstration blocks | | | Trees in demonstration blocks | | |
| | Healthy | Blotched | Other diseases and insect injuries | Healthy | Blotched | Other diseases and insect injuries | Healthy | Blotched | Other diseases and insect injuries | Healthy | Blotched | Other diseases and insect injuries | Healthy | Blotched | Other diseases and insect injuries | Healthy | Blotched | Other diseases and insect injuries |
| | % | % | % | % | % | % | % | % | % | % | % | % | % | % | % | % | % | % |
| 1 | 94 | 2 | 4 | 90 | 1 | 9 | — | — | — | — | — | — | — | — | — | — | — | — |
| 2 | 88 | 12 | 5 | 89 | 8 | 3 | — | — | — | — | — | — | — | — | — | — | — | — |
| 3 | 79 | 6 | 15 | 89 | 1 | 10 | — | — | — | — | — | — | 80 | 16 | 4 | 98 | 0.2 | 1.8 |
| 4 | 66 | 9 | 25 | 64 | 4 | 32 | 62 | 32 | 6 | 81 | 13 | 6 | — | — | — | — | — | — |
| 5 | — | — | — | — | — | — | 75 | 21 | 4 | 88 | 7 | 5 | — | — | — | — | — | — |
| 6 | 54 | 26 | 20 | 80 | 5 | 15 | — | — | — | — | — | — | — | — | — | — | — | — |
| Average | 75 | 11 | 14 | 82 | 4 | 14 | 68 | 26 | 5 | 84 | 10 | 6 | 80 | 16 | 4 | 98 | 0.2 | 1.8 |

Average for all blocks: Outside trees—Healthy 74%, blotched 18%; Demonstration—Healthy 88%, blotched 5%.

Season of 1924

The tests of 1924 differed from those of 1923 in several respects. A 2-4-50 Bordeaux mixture was used instead of the 3-4-50 mixture of the preceding year; the test blocks were enlarged to the number of trees which could be sprayed with one 200-gallon tank of mixture; and the tests were conducted in six commercial orchards instead of four as in 1923. The weaker Bordeaux mixture, 2-4-50, was used because of the satisfactory results obtained with it by the Indiana Experiment Station, where blotch was effectively controlled and the percentage of Bordeaux injury, known as russetting, was reduced.

Table 2 gives the results obtained in 1924 on the Early Harvest, Duchess and Yellow Transparent varieties.

The results presented in Table 2 show that the 2-4-50 Bordeaux mixture is effective in the control of blotch on early apples in Tennessee. As a result of the 1923 tests, growers had learned that thoroughness pays; therefore they sprayed the trees outside the test blocks much more thoroughly in 1924 than in 1923. The better control obtained in 1924 on trees outside the test blocks as compared with 1923 results indicates that thoroughness of application is a very important factor.

In all cases both in 1923 and 1924 a caseinate of lime spreader (Kayso) was added to the special sprays used on the test blocks, and this material appeared to facilitate the thorough covering of the fruit, leaves, and twigs.

CONCLUSIONS

From the results obtained during the seasons of 1923 and 1924 the conclusion cannot be reached that Bordeaux mixture is enough more effective than lime-sulphur for the calyx spray to justify a change in the present spray schedule.

The results obtained with the 2-4-50 Bordeaux mixture in 1924 when compared with those obtained with 3-4-50 and 4-5-50 in 1923 indicate that the weaker Bordeaux is as effective in disease-control and results in less Bordeaux injury.

The successful control of diseases in the test blocks of all orchards in 1923 and 1924 indicates the importance of thoroughness. This was substantiated by the fact that the more thorough spraying of the growers in 1924 resulted in a great reduction in diseases as compared with 1923. A majority of the growers in whose orchards these tests were conducted stated that in their opinion the degree of thoroughness of the application is a more important consideration than the material to be used.

RECOMMENDATIONS

As a result of the two years' tests it is recommended that for blotch control on early apples, at least four summer sprays be applied—starting with the calyx spray, followed at two-week intervals with subsequent sprays. If apple scab is serious, a pink-bud spray with lime-sulphur (see schedule, page 4) should precede the calyx, or first blotch, spray.

Both lime-sulphur and 2-4-50 Bordeaux mixture have proved effective in blotch control in the calyx spray, and either should give satisfactory results if thoroughly applied. The addition of a caseinate of lime spreader to the spray mixture probably facilitates thoroughness of application.

Acknowledgments: Much of the success of these tests is due to the hearty cooperation of N. B. Rue, Henry Pointer, Lucius P. Brown, T. H. Barrow, Horace Rainey, Jr., and I. C. Murphy, in whose orchards these tests were conducted. Credit is also due N. D. Peacock, of the College of Agriculture, for helpful suggestions and assistance in initiating the 1923 tests.



FRUIT FROM A TEST BLOCK SPRAYED ONE YEAR

The rear twelve bushels of fruit are healthy; there is a small amount of cedar rust, russet, and insect injury on the inverted baskets, and of blotch and rosy aphid in the two partly filled baskets in the foreground. This shows the large percentage of healthy fruit produced by proper spray methods.

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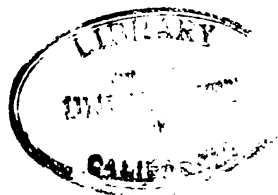
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EXCHANGE
APR 29 1926
DECEMBER, 1925

THE CORN EAR WORM ON TOMATO

By

S. MARCOVITCH AND S. A. ROBERT



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SUPPLEMENTARY INVESTIGATIONS OF THE FLUOSILICATES AS INSECTICIDES

With Observations on the Effect of Heat and Drouth on the Mexican Bean Beetle

INTRODUCTORY

The first extensive experiments with the fluosilicates as insecticides were carried out at Knoxville in the spring of 1924, with special reference to the Mexican bean beetle.

The sodium salt was the only one available in commercial quantities, and it was not particularly well adapted for dusting. The product as manufactured by the Virginia-Carolina Chemical Company seemed to be the best obtainable for use as a dust. Their material was fairly dense, occupying in the neighborhood of 38 to 40 cubic inches to the pound.

Comparatively favorable results were obtained, which were reported in Bulletin 131 of this Station. Since these results were published one manufacturer has placed a light sodium fluosilicate on the market, and there has also appeared a commercial calcium fluosilicate. These chemicals were tried out in the field during the season of 1925, and much additional information was obtained. The results are not conclusive, however, due to the hot, dry summer, which kept the bean beetles from multiplying.

SODIUM FLUOSILICATE (LIGHT AND EXTRA LIGHT)

To meet the requirements for a good dusting material, Jungman & Company, of New York City, have placed on the market two brands, known as "light" and "extra light." The former contains 80 to 85 per cent sodium fluosilicate and the latter 70 to 75 per cent. According to the distributors, the remainder consists of silica. It was found, however, to be alumina, which was used as a colloid to make a bulkier precipitate. The "extra light" material occupies about 60 cubic inches to the pound, and represents a decided improvement as far as bulk is concerned. The "light" sodium fluosilicate occupies about 45 cubic inches. Since the commercial product as put out by the Virginia-Carolina Chemical Company occupies about 38 cubic inches, there is not much difference in this respect. The latter contains, however, from 98 to 99 per cent sodium fluosilicate.

The "extra light" material was used this year in the experimental tests in the field. The fluosilicate content of this material is only about 70 per cent, and the tests showed proportionately less toxicity. When mixed with lime it was decidedly inferior to the commercial material. For many insects, there appears to be sufficient toxicity when the "extra light" is used undiluted. For insects that feed sparingly, such as the boll weevil, the large amount of filler detracts seriously from the value of the material. It was also found to be considerably safer on foliage. As far as could be ascertained, no foliage injury resulted when this material was used undiluted on beans, cotton, or cucumbers. The only plant on which serious injury occurred was tobacco.

SIZE OF PARTICLES OF FLUOSILICATES

The physical condition of a material to be used as a dust is a matter of much importance, demanding a good deal of attention. For the best results, the insecticide should be bulky in proportion to weight, so as to cover a large area; the particles should be small, yet dense enough to settle and not float away; and the adhering properties should be such as to prevent its being easily washed off by rain. If the dust can be given a positive charge of electricity the sticking qualities will be increased because leaf surfaces have a negative charge. The addition of a tri-valent ion, such as iron, has been found to reverse the charge of calcium arsenate from negative to positive.

An examination of the commercial fluosilicates revealed a wide variation in the size of the particles, as shown in Table 1.

TABLE 1—*Size of particles of fluosilicates*

| Source of material | Microns | Remarks |
|--------------------------------------|---------|------------|
| Sodium fluosilicate | | |
| Commercial (Jungman) | 20-100 | Mostly 100 |
| "Extra light" (Jungman) | 5- 30 | |
| Commercial (Virginia-Carolina) | 7- 20 | Mostly 15 |
| Calcium fluosilicate (Victor) | 4- 8 | Mostly 5 |

In a good grade of calcium arsenate the particles appear to be from 2 to 4 microns in size. It is therefore apparent that a material with particles of the size of 100 microns is poorly adapted for dusting.

The particles of the calcium fluosilicate compound are fairly good, as far as size is concerned, being for the most part in the neighborhood of 5 microns. They do not settle on the plants, however, when a light breeze is blowing, because they are porous. As they are also round they easily roll off the leaves.

Although the commercial sodium fluosilicate of the Virginia-Carolina Chemical Company is heavy, it dusts well when mixed with hydrated lime. Lime was found to have excellent sticking qualities, which may be partly explained by the fact that it carbonates readily in the air.

CALCIUM FLUOSILICATE

The original experiments with calcium fluosilicate as an insecticide were made with material obtained from Eimer and Amend, marked

"C. P." This chemical was found very toxic to both the insects and the plants, which indicates that it is soluble. A careful search of the literature revealed the fact that it is considered slightly soluble, although no figures were given. When it was mixed with water a marked acid reaction could be detected, indicating hydrolysis. A gram of the material was washed ten times with distilled water. The first leachings gave heavy precipitates with barium chloride and potassium chloride, indicating the presence of a soluble fluosilicate. The filtrate also gave a precipitate with sodium phosphate and ammonium oxalate, indicating a calcium salt.

It was evident that a large proportion, perhaps 20 per cent, of the so-called C. P. calcium fluosilicate was soluble. About 12 grams was washed in like manner, and the washed material was tested in the field. This washed material showed no toxicity and no burning. At this time the Victor Chemical Works became interested in the problem and kindly made a chemical analysis of the material. They reported that this sample, marked "Calcium Silicofluoride C. P.," consisted of approximately 30 per cent soluble calcium fluosilicate and 70 per cent calcium fluoride and silica. Their findings at once afforded an explanation of the burning properties exhibited by the material. Further research by the Victor Chemical Works showed that a pure calcium fluosilicate properly prepared is very soluble. When phosphates are introduced into a solution of calcium fluosilicate, however, precipitation takes place, forming, most probably, a double compound with phosphates.

Calcium fluosilicate as manufactured by the Victor Chemical Works

TABLE 2—*Tests of insecticides used as dusts against the Mexican bean beetle under cages—10 beetles under each cage*
Rate of application, about 30 pounds to acre

| Material or compound | Date of application | Number dead | | | | | | Total dead | Injury to bean foliage | Temperature | |
|--|---------------------|-------------|---------|---------|---------|---------|---------|------------|------------------------|-------------|---------|
| | | 8 hrs. | 24 hrs. | 32 hrs. | 48 hrs. | 56 hrs. | 72 hrs. | | | High-est °F | Mean °F |
| Sodium fluosilicate (Va.-Car.) | July 9 | 6 | 2 | 1 | 0 | 1 | 0 | 10 | None | 92 | 82 |
| Sodium fluosilicate (Jungman) | July 3 | 0 | 9 | 0 | 0 | 0 | 1 | 10 | None | 99 | 84 |
| Sodium fluosilicate (Jungman) | July 9 | 3 | 5 | 0 | 2 | 0 | 0 | 10 | None | 92 | 82 |
| Sodium fluosilicate (Smith) | July 6 | 0 | 7 | 0 | 2 | 1 | 0 | 10 | None | 92 | 82 |
| Calcium fluosilicate (Victor) | July 3 | 9 | 1 | 0 | 0 | 0 | 0 | 10 | None | 99 | 84 |
| Calcium fluosilicate (Victor) | July 9 | 10 | 0 | 0 | 0 | 0 | 0 | 10 | None | 92 | 82 |
| Calcium fluosilicate (Wiarda) | July 13 | 9 | 10 | 0 | 0 | 0 | 0 | 10 | None | 96 | 82 |
| Barium fluosilicate | July 6 | 6 | 0 | 0 | 0 | 0 | 0 | 6 | None | 92 | 82 |
| Barium fluoride | July 6 | 0 | 0 | 2 | 0 | 0 | 4 | 6 | Slig't | 92 | 82 |
| Cryolite (Jungman) | July 13 | 9 | 10 | 0 | 0 | 0 | 0 | 10 | | 96 | 82 |
| Potassium fluosilicate C. P. | July 13 | 9 | 9 | 1 | 0 | 0 | 0 | 10 | | 96 | 82 |
| Sodium fluosilicate 2 lbs. to 50 gals. | July 7 | 0 | 2 | 0 | 2 | 2 | 2 | 8 | | 91 | 80 |

is not readily soluble, owing to the fact that it is precipitated in the presence of phosphates. Their material is a by-product in the volatilization method of treating phosphate rock for phosphoric acid. For insecticide purposes, this product was sold under the name of "Calcium Fluosilicate Compound." The material is light and fluffy, and is marketed in two forms, one occupying approximately 70 cubic inches to the pound and the other approximately 120 cubic inches to the pound. It was found very safe on foliage, producing no noticeable burning, even on tobacco. Great improvement could be made in its adhering properties, and we learned through correspondence that experiments have been conducted to this end with encouraging results. We are also informed that the Victor Chemical Works have discovered a method of increasing the calcium fluosilicate content of their product which should materially enhance its toxicity.

A large number of cage experiments and a few field tests were made to determine the toxicity of calcium fluosilicate compound toward insects. According to Table 2, when this material was used at the rate of 30 pounds to the acre, with high temperatures prevailing, the kill obtained against the bean beetle was excellent. When the dosage was cut down to 5 pounds per acre, the beetles were not noticeably affected, as shown in Table 3. In one field test the compound was applied once, May 26, at the rate of about 35 pounds to the acre. There was a medium infestation present, with 10 beetles to the row. On June 19, the infestation was only about 5 per cent, whereas the check showed 50 per cent.

TEST WITH THE FLUOSILICATES ON OTHER INSECTS

The Cucumber Beetle (*Diabrotica vittata*).—The control of the cucumber beetle has heretofore been far from perfect. It is a very difficult insect to poison, the arsenicals, as Howard¹ states, being "more or less repellent." Recently nicotine dusts have been recommended, but these are expensive and must be applied several times for satisfactory control.

Since this beetle has the habit of cleaning its feet by drawing them through its mouth, it would be expected to yield to the fluosilicates, and such was found to be the case. On June 12 several rows of cucumbers were dusted lightly with sodium fluosilicate about seven o'clock in the morning. Eight hours later dead beetles were found under the plants, and it was difficult to find a live specimen. The control obtained was practically 100 per cent. With the commercial sodium fluosilicate, foliage injury appeared within 3 days. After a few weeks, however, the plants outgrew the injury. If the commercial material be used, it should be diluted with 3 parts of lime. The "extra light" sodium fluosilicate also gave satisfactory control, and no burning. Cage tests showed that heavy applications of calcium fluosilicate compound gave good control, especially when high temperature prevailed.

The Tobacco Hornworm (*Protoparce quinquemaculata*).—The tobacco plant is very susceptible to foliage injury by the soluble fluosilicates. Several of the Station plots were dusted with the "extra light" material, but the injury that resulted was not sufficient to attract the attention of the foreman. The control of the hornworm was satisfactory, a kill having been obtained within from 8 to 36 hours. The calcium fluosilicate compound killed the worms within from 12 to 48 hours and gave no foliage injury. Barium fluosilicate killed the worms within 6 hours, with no foliage injury. Cryolite, both natural and artificial, and aluminum fluosilicate were also safe on the foliage while toxic to the worms.

¹Howard, N. F. Insecticide Tests with *Diabrotica vittata*. Jour. Econ. Ent. 11: 75. 1918.

TABLE 3—Tests of insecticides used as dusts against the Mexican bean beetle under cages—10 beetles under each cage
Rate of application, about 5 pounds to acre

| Material or compound | Date of application | Number dead | | | | | | Total dead | Injury to bean foliage | Temperature | |
|-----------------------------------|---------------------|-------------|---------|---------|---------|---------|---------|------------|------------------------|-------------|---------|
| | | 8 hrs. | 24 hrs. | 32 hrs. | 48 hrs. | 56 hrs. | 72 hrs. | | | High est °F | Mean °F |
| Sodium fluosilicate (Va.-Car.) | July 27 | 2 | 3 | 2 | 2 | 1 | 0 | 10 | None | 90 | 82 |
| Sodium fluosilicate (Va.-Car.) | July 29 | 2 | 0 | 2 | 2 | 2 | 1 | 9 | None | 83 | 74 |
| Sodium fluosilicate (Jungman) | July 30 | 10 | 0 | 0 | 0 | 0 | 0 | 10 | None | 92 | 76 |
| Sodium fluosilicate (Jungman) | July 29 | 0 | 0 | 1 | 2 | 2 | 2 | 7 | None | 83 | 74 |
| Calcium fluosilicate (Victor) | July 27 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | None | 90 | 82 |
| Check | July 27 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | None | 90 | 82 |
| Sodium fluosilicate C. P. (Baker) | Aug. 10 | 0 | 0 | 4 | 1 | 0 | 5 | 10 | None | 98 | 84 |
| Sodium fluosilicate C. P. (Baker) | Aug. 10 | 0 | 0 | 4 | 5 | 1 | 0 | 10 | None | 98 | 84 |
| Sodium fluosilicate C. P. | Aug. 14 | 7 | 2 | 1 | 0 | | | 10 | None | 86 | 78 |
| Sodium fluosilicate (Jungman) | Aug. 10 | 0 | 1 | 1 | 0 | 4 | 2 | 8 | None | 98 | 84 |
| Sodium fluosilicate (Jungman) | Aug. 10 | 1 | 2 | 3 | 0 | 1 | 2 | 9 | None | 98 | 84 |
| Sodium fluosilicate (Jungman) | Aug. 14 | 0 | 2 | 3 | 2 | 0 | 1 | 8 | None | 86 | 78 |
| Sodium fluosilicate (Va.-Car.) | Aug. 14 | 2 | 3 | 2 | 1 | 0 | 1 | 9 | None | 86 | 78 |
| Calcium fluosilicate (Victor) | Aug. 14 | 0 | 0 | 3 | 2 | 1 | 0 | 6 | None | 86 | 78 |
| Check | Aug. 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | None | 98 | 84 |
| Check | Aug. 14 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | None | 86 | 78 |

Since sodium fluosilicate readily injures tobacco, its use is not recommended.

The Sinuate-Striped Flea Beetle (*Phyllotreta sinuata*).—This flea beetle was found abundant on a species of cruciferae, and is known as a pest of turnips. Since flea beetles in general have not been satisfactorily controlled by arsenicals, experiments were carried out against this species. Cage tests showed that they yielded to the sodium fluosilicate within 24 hours. An infestation of the potato flea beetle (*Epitrix cucumeris*) occurred at Crossville, Tennessee, and good control was reported from the use of sodium fluosilicate diluted with 4 parts of lime.

The writer was informed that the potato flea beetle is being successfully combated in Maine by the "extra light" sodium fluosilicate. Gentner² found that the mint flea beetle (*Longitarsus menihae*), a new pest on mint, has appeared in threatening numbers in Michigan. Satisfactory control of this pest was obtained the past season with calcium fluosilicate compound.

Blister Beetles (*Epicauta* sp. and *Macrobasis unicolor*).—In

²Gentner. The Mint Flea Beetle. Quarterly Bul. Mich. Agr. Exp. Sta. 7:3. 1925.

Arkansas, Baerg³ found that blister beetles, heretofore not successfully controlled, are very susceptible to the fluosilicates. These beetles are especially injurious to soybeans, on which they are often found in swarms. The sodium fluosilicate caused no appreciable injury to soybean foliage or alfalfa when diluted with an equal quantity of hydrated lime.

Cutworms.—The usual method of cutworm control consists of the use of poisoned bran mash, in which an arsenical is the active killing agent. When sodium fluosilicate or calcium fluosilicate was substituted, in the proportion of 1 to 10 or 20 parts of bran, the worms were found dead, under laboratory conditions, within from 7 to 24 hours. Similar results were obtained with the red-legged grasshopper (*Melanoplus femurrubrum*).

Ripley⁴ found that they "never had a perfect cutworm bait in South Africa." He found that arsenite of soda and Paris green repel the larvae, but that a 2 per cent solution of sodium fluoride gives excellent results. Since sodium fluosilicate is more toxic than sodium fluoride, and appears to be readily eaten, the fluosilicates should prove satisfactory substitutes for arsenicals in poison baits.

Cotton Worm.—An infestation of cotton worms (*Alabama argillacea*) occurred at Knoxville October 8, 1925, and afforded an opportunity to test the value of the fluosilicates against this insect. In cage tests the worms succumbed to sodium fluosilicate within 7 hours, whereas under the calcium arsenate treatment they survived 24 hours or longer. The calcium fluosilicate compound did not prove effective against the cotton worm, many larvae being found alive after 5 days.

Ants.—A few experiments showed that ants in a dwelling can be kept in check by the sprinkling of sodium fluosilicate in places which they frequent. Similarly, by the dusting of cotton in the greenhouse ants were kept from tending and spreading the cotton louse.

Roaches.—Sodium fluoride is known to be effective against roaches. Several bad infestations of *Blatta orientalis* and *Blatella germanica* located during the past summer offered opportunity for testing sodium fluosilicate. In all cases the roaches were effectively controlled by the sprinkling of the powder in the corners on the pantry floors. In a few cases dead mice were also found in the pantries after the use of sodium fluosilicate.

Clothes Moth.—Several clothes-moth remedies have appeared on the market. For one of them, "Larvex," it is claimed that the spraying of blankets and woolen fabrics makes these articles proof against further infestation. The writer's attention was drawn to the fact that "Larvex" is merely a solution of sodium fluosilicate with a small amount of colloidal material to aid in wetting. A few laboratory experiments with nearly full-grown larvae of the case-building clothes moth (*Tinea pellionella*) showed that they could be killed within 6 hours by being allowed to feed on raw wool which had been dipped in a ½ per cent solution of sodium fluosilicate. Larvae allowed simply to crawl over the powder for 8 days were not affected. To produce results the powder must be eaten.

"Larvex" contains about one ounce per gallon of sodium fluosilicate, and is expensive. An equally effective material may be made at a very much lower cost.

³Baerg, W. J. Control Measures for Blister Beetles. Bul. Ark. Agr. Exp. Sta. 201. 1925.

⁴Ripley, L. B. Experiments with Cutworm Baits: Success with Sodium Fluoride. Memoir Union of S. Africa Dept. of Agr. 3. 1925.

COMPATIBILITY WITH FUNGICIDES, AND GERMICIDAL
VALUE OF THE FLUOSILICATES

The question arose whether the fluosilicates could be used in combination sprays with lime-sulphur or Bordeaux mixture. In the case of calcium fluosilicate there appears to be little chemical action with either lime-sulphur or Bordeaux. Sodium fluosilicate, however, precipitates sulphur out of the lime-sulphur solution, and the two are therefore not compatible, especially for use on apples. The Bordeaux mixture seems to produce a slight reaction with the sodium fluosilicate, but not enough to destroy the properties of either. This combination was not injurious to potato foliage, and was toxic to the larvae of the potato beetle, as shown in Table 4.

TABLE 4—*Tests of insecticides against the Colorado potato beetle under cages*

| Material or compound | Date of application | Date first beetles died | Date last beetles died | Injury to plant | Notes |
|--|---------------------|-------------------------|------------------------|-----------------|--|
| Barium fluosilicate | May 18 | May 18 | | None | All larvae dead in 5 hours. Material sticks very well to foliage. Does not stick well. |
| Barium fluoride | May 18 | May 18 | May 20 | None | |
| Calcium fluosilicate (Victor) | May 18 | May 19 | May 20 | None | |
| Calcium fluosilicate, 1 lb. to 50 gals. water | May 18 | May 20 | | None | Has very little killing power. |
| Sodium fluosilicate plus 8 parts gypsum | May 18 | May 18 | May 19 | None | Many dead in 4 hours. |
| Sodium fluosilicate plus 8 parts lime | May 18 | May 18 | May 19 | None | The lime sticks well to the foliage. |
| Sodium fluosilicate 2 lbs. to 50 gals. water plus 2 lbs. lime | May 22 | May 23 | May 24 | None | |
| Sodium fluosilicate, 2 lbs. to 50 gals. water plus Bordeaux 3-3-50. | May 22 | May 23 | May 24 | None | |
| Sodium fluosilicate, 2 lbs. to 50 gals. water plus lime-sulphur 1-40 | May 22 | May 23 | May 24 | None | |
| Ziderite | June 4 | June 5 | June 6 | None | All dead in 2 hours. |
| Potassium fluosilicate | June 9 | June 9 | June 9 | None | |
| Aluminum fluosilicate | June 9 | June 9 | June 9 | None | All dead in 2 hours. |
| Aluminum fluoride | June 9 | June 9 | June 9 | None | |
| Calcium fluosilicate (Wiarda) | June 17 | June 17 | June 17 | None | All larvae dead in 4 hours. |

In a paper presented before the American Phytopathological Society, December 31, 1925, Dr. H. W. Anderson, of Illinois, discussed "The Control of Bacterial Spot of Peach with Sodium Silicofluoride." Bacterial spot (*Bacterium pruni*), considered the most serious disease of the peach in Illinois, is not controlled by the ordinary fungicides. Dr. Anderson found that sodium silicofluoride in dilutions ranging from 1-4,000 to 1-4,500 would always render both sterile when inoculated with *Bacterium pruni*. Sodium silicofluoride was found only moderately fungicidal, inhibiting the germination of spores of *Flomerella cingulata* in dilutions of 1-800 when added directly to the spores in suspension. Field tests showed practically no infection of bacterial spot, whereas those trees not sprayed with sodium silicofluoride showed 20 to 80 per cent of the leaves infected.

SPRAYING WITH FLUOSILICATES

Experiments with a solution of sodium fluosilicate were carried out in 1924 in the greenhouse. Some injury of the foliage occurred, due probably to the humid conditions prevailing. In 1925, a $\frac{1}{2}$ per cent solution was used out-of-doors on beans, peaches, and apples, with no noticeable injury. This strength was sufficient to kill adults and larvae of the bean beetle within from 10 to 72 hours.

On July 28 a plot of beans was sprayed with sodium fluosilicate at the rate of 2 pounds to 50 gallons of water. A count July 31 revealed 39 dead beetles in one row 45 feet long.

IS IT NECESSARY TO DUST THE UNDERSIDE OF LEAVES?

Since the larvae of the bean beetle feed on the lower epidermis of the leaves, all of the recommendations to date have advised that the applications of dust or spray be made to the underside of the leaves. But the adult bean beetle is frequently found crawling over the tops of the leaves, and even though it feeds from the underside, the beetle bites through the leaf and actually swallows parts of the upper epidermis. With the fluosilicates, the irritation produced on the adults causes them to lick their feet and thus obtain a toxic dose. If control measures are directed against the adults, as has been advised with the fluosilicates, the dust should, theoretically, not have to be placed on the underside of the leaves. In all of the cage experiments the past summer, the dust was applied entirely to the top of the leaves, and a good kill was obtained, as shown in Table 1. The beetles were not abundant enough to test this point thoroughly in the field; yet there was some indication that control could be effected in this manner.

When it is considered that it takes approximately eight hours to dust an acre of beans on the underside of the leaves with a bellows duster and only about one hour to dust the top with a rotary hand-gun, the advantage of the latter method is obvious. Of course if the adults are not controlled, and a crop of larvae appear, it becomes necessary to dust or spray the underside of the leaves. A timely application of dust, however, to the top of the leaves may be easily made to kill the adults and prevent an infestation.

NATURAL CONTROL EFFECTED BY HEAT

Graf⁵ states that the Mexican bean beetle is believed to be a native of the plateau region of Southern Mexico. In that area it has been reported only from altitudes above 4,000 feet. Mexico City has an elevation of 7,350 feet, a mean summer temperature of 60°F to 65°F., and about 4

⁵Graf, J. E. Climate in Relation to Mexican Bean Beetle Distribution. Jour. Econ. Ent. 18: 116. 1925.

inches of rainfall during the summer months. These ranges are probably the optimum conditions for the beetle.

At Albuquerque, New Mexico, the mean summer temperature ranges from 70°F. to 76°F., and summer rainfall from $\frac{3}{4}$ inch to 1½ inches. Until the introduction of the beetle into the Southeastern United States it was believed that the insect was confined to the Southwest because of the semi-arid conditions prevailing there. Chittenden⁶ states that "cold weather appears to be the most important natural check to the development of the bean ladybird in Colorado."

It was therefore of considerable interest to note the adaptability of the beetle to the comparatively humid conditions prevailing in the Southeastern United States. With normal temperatures and rainfall prevailing in the Southeast during 1920 and 1921, the beetle became extremely abundant around Birmingham. In 1922 Howard⁷ found the infestation much lighter, owing to the prolonged hot, dry period in 1921.

In the vicinity of Knoxville a dry spell occurred in August, 1924, and a decline in the abundance of the insect was observed. The average rainfall for August at Knoxville is 4 inches, with a temperature of 76°F., whereas only 1.77 inches fell, with a mean temperature of 78°F. In 1925, an unparalleled drouth occurred in Knoxville and vicinity, so that the effects of hot, dry weather were strikingly apparent. The insect became much reduced in numbers, making it difficult to obtain specimens. It seems likely that the beetle is better adapted to the cool tablelands of Mexico than to our Southwest. Certain it is that the humid conditions prevailing in the Eastern United States are most favorable to this insect.

TABLE 5—*Temperature and rainfall at Knoxville*

| Month | Temperature
1925 | Normal
average | Precipitation
1925 | Normal
average |
|-----------|---------------------|-------------------|-----------------------|-------------------|
| | °F | °F | Inches | Inches |
| January | 41.5 | 39.0 | 3.76 | 4.97 |
| February | 47.2 | 42.0 | 2.56 | 4.90 |
| March | 52.0 | 49.0 | 1.10 | 5.58 |
| April | 63.0 | 58.0 | 2.30 | 4.64 |
| May | 64.0 | 67.0 | 2.40 | 3.70 |
| June | 78.4 | 74.0 | 1.78 | 4.17 |
| July | 80.0 | 77.0 | 1.46 | 4.21 |
| August | 78.6 | 76.2 | 1.63 | 4.00 |
| September | 79.7 | 70.6 | 2.48 | 2.81 |
| October | 56.9 | 59.9 | 9.51 | 2.61 |

A glance at the record of temperature and rainfall shown in Table 5, reveals the very abnormal weather conditions that prevailed in 1925. The figures do not, however, give an adequate conception of the extreme drouth, because the little rain that fell came in small, scattered showers, with not a soaking rain during the spring or summer months. Maximum temperatures of 100°F. to 102°F. were reached several times in September, with bright sunshine and a singular absence of clouds. By late September there had accumulated an excess temperature of 664°F., since March 1, with a deficiency in rainfall of 16 inches.

⁶Chittenden, F. H. The Bean Ladybird. Bul. U. S. Dept. of Agr. 843. 1920.

⁷Howard, N. F. Studies of the Mexican Bean Beetle in the Southeast. Bul. U. S. Dept. of Agr. 1243, 1924.

On June 15, the temperature was 90°F. in the shade at 11 o'clock. Out in the open and only a few inches from the ground, the thermometer registered 120°F., while the surface of the ground showed 140°F. Since a temperature of 120°F. for several hours is known to be fatal to many insects, it is not surprising that the larvae of the bean beetle should have succumbed to the excessive heat. The first instar larvae are very susceptible to direct sunlight, as has been shown by Howard. He found that an exposure of two minutes to direct sunlight was fatal when the temperature was 96°F. in the shade.

The adults were present in fair numbers at Knoxville on July 30, and deposited large numbers of eggs. Nevertheless it was difficult to find any larvae, for they appeared to dry up as fast as the eggs hatched. Usually the beetle prefers garden beans to lima beans, but under dry, hot weather conditions, the beetle appeared to lay more eggs on lima beans, due to their greater capacity for shading the ground.

As a result of the drouth, only a few beetles survived to go into hibernation, and much relief from their depredations is expected the coming spring. Drouth rather than cold appears to be the limiting factor in the multiplication of the insect.

RECOMMENDATIONS FOR THE CONTROL OF THE MEXICAN BEAN BEETLE

Control is simplified by the use of fluosilicates, since the attack is made on the adult beetles. The bean patch should be examined frequently, and as soon as 5 beetles are found to each 50 feet of row it should be dusted with one of the following mixtures:

| | Pounds per acre |
|---|-----------------|
| Sodium fluosilicate (commercial) 1 part | } ----- 20 |
| Hydrated lime..... 2 parts | |
| Calcium fluosilicate compound | 30 |
| Sodium fluosilicate (extra light) | 15 |

If the application is made before many eggs are laid, the dust may be applied to the top of the plants. If egg-laying is under way, or if larvae are present, it would be advisable to direct the dust to the underside of the leaves. Good results may be obtained with a rotary fan duster by turning the nozzle sideways. A second and a third application, at intervals of a week, may be necessary if the beetles are abundant.

SUMMARY

1. In addition to the commercial sodium fluosilicate, a "light" and an "extra light" form are now obtainable in commercial quantities. The "extra light," containing about 70 per cent sodium fluosilicate, was effective against some insects and was found to be safe on foliage, except tobacco.

2. A by-product, "calcium fluosilicate compound," was marketed the past summer. This product is not readily soluble, is safe on foliage, and effective as an insecticide when applied in heavy doses. It is not as toxic as sodium fluosilicate when used at the same rate.

3. The fluosilicates were found especially effective against the striped cucumber beetle, blister beetles, and several flea beetles. In laboratory tests cutworms and grasshoppers readily succumbed to a bait composed of 20 parts of bran and 1 part of fluosilicate.

4. Sodium fluosilicate gives promise of becoming a valuable material for the control of bacterial spot of peach (*Bacterium pruni*).
5. Fluosilicate dusts applied to the top of bean plants under cages were found effective against adult Mexican bean beetles.
6. The larvae of the Mexican bean beetle are very susceptible to extremes of heat and drouth.

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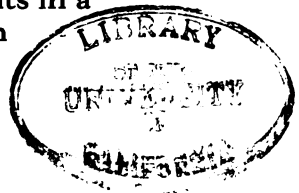
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MAY, 1926

EFFECTS OF LIMING AND GREEN MANURING ON CROP YIELDS AND ON SOIL SUPPLIES OF NITROGEN AND HUMUS

Results of 20 Years' Experiments in a
Cowpea-Wheat Rotation

By
C. A. MOOERS



Harvesting the cowpea crop

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Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

EFFECTS OF LIMING AND GREEN MANURING ON CROP YIELDS AND ON SOIL SUPPLIES OF NITROGEN AND HUMUS

By
C. A. MOORE

INTRODUCTION

The influence of the cowpea crop on the productivity of the soil is a subject of debate among practical farmers. Some have found cowpeas to benefit the soil, even when the crop was removed for hay. The effect on close, heavy soils is to make them more open and porous, so that for the time they seem rejuvenated, especially when well supplied with plant food. Soils impoverished by long cropping in cotton, corn, or the like, may be improved by a good crop of cowpeas, because of the residue of roots, stubble, and fallen leaves. Some farmers, on the other hand, especially those who have fertile loams, such as are found in the Central Basin, complain that cowpeas make the soil too open and granular, causing greatly increased damage from erosion. They also contend that this crop does little to increase the productiveness of the soil, and in that particular is not to be classed with red clover.

At a number of experiment stations, particularly in the South and West, work has been done with a view to determining the effect of cowpeas on succeeding crops of various kinds. The literature on the subject was reviewed in an article on "Green Manuring" by A. J. Pieters, of the Bureau of Plant Industry, U. S. Department of Agriculture, published in the *Journal of the American Society of Agronomy* in 1917 (Vol. 9, No. 2, 3, and 4). The general conclusion reached in this review is that the residual effect of a cowpea crop turned under was marked, "while that of the stubble was sometimes evident but slight". Much the same conclusion can be reached from a perusal of later work. Most of the experiments, both those reviewed and those carried out since then, were not continued long enough for the satisfactory demonstration of the influence of this crop. Recently, however, a publication by Garner, Lunn, and Brown gives results for a 12-year period in a 2-year rotation of wheat, cowpeas, and tobacco, the cowpeas being turned under in comparison with other green-manure crops. During the initial years the tobacco crops following cowpeas were large, but the trend for the period was decidedly downward.

¹Garner, W. W., Lunn, W. M., and Brown, D. E. Effects of crops on the yields of succeeding crops in the rotation, with special reference to tobacco. *Jour. Agr. Research* (U. S.). 30: 1095-1132. Dec. 1925.

For many years agricultural writers have called attention to the divergent views and practices of farmers in regard to liming. Adam Dickson, in his "Treatise on Agriculture", published in Edinburgh in 1765, pointed out that there were two opposite opinions, one that lime acts only as a soil stimulus, "making the soil with which it is mixed exert itself", and the other that "it promotes vegetation by enriching the land and adding to the quantity of vegetable food." This latter opinion, he says, "is supported by observing that in some places lime is applied regularly once in four or five years; that the land seldom gets any other manure, but is kept almost constantly in tillage and with the assistance of fallowing carries very good crops". His final observation is that "one is led to conclude that lime acts both ways; not only makes land exert itself in the nourishment of vegetables but also enriches it."

In recent years much attention has been given by agricultural investigators to the subject of liming. Data have been obtained with regard to both the lime requirements of various soils and the relative response of different crops. In addition considerable success has attended the efforts to determine the underlying reactions involved in liming. This latter sort of investigation is especially valuable, because every advance in this direction tends to the rational and judicious use of an important soil amendment.

This publication deals principally with the results obtained in 2 series of experiments, one conducted for 20 years at Knoxville, in the eastern part of the State, and the other for 16 years at Jackson, in the western part of the State—a rotation of cowpeas and wheat being used at each place. The 2 crops were grown annually under various conditions of liming, manuring, and fertilizing, in connection with both the turning under and the removal of the cowpea crops. In addition, comparable data were obtained at Knoxville in a parallel series of experiments in a 5-year rotation of corn, wheat, soybeans, and clover and grass, extending over the same 20-year period.

The liming data from the Knoxville experiments are of special interest for two reasons; first, the effects of liming with burnt lime are followed in the cowpea-wheat rotation as long as discernible in either crop production or changes in the nitrogen content of the soil; second, the data obtained after reliming in this rotation, supplemented by those from the 5-year rotation, afford the proof of much that has been a matter of surmise on the part not only of Adam Dickson but of many others since his day. That is, the data show that for certain crops, including not only cereals but also such legumes as cowpeas and soybeans, the periodical liming of the land may act almost entirely as a soil stimulant—the stimulation being of limited duration and following the law of diminishing returns—while for certain other crops, such as alsike and red clover, periodical liming may continue for an indefinite time to be highly effective.

RESULTS OBTAINED AT THE KNOXVILLE STATION IN THE COWPEA-WHEAT ROTATION

PREVIOUS PUBLICATIONS

Two Tennessee Station bulletins, No. 90 and 96, give the results for the first 5 years of the experiments. No. 90 relates to the utilization of various phosphates; No. 96 discusses (1) "the effect of liming on the crop production", and (2) "the effect of liming and green manuring on the soil content of nitrogen and humus". These bulletins give numerous details concerning the experiments. Those of most importance to the present purpose are reviewed in the following pages and all the experimental data are included in the tables contained in this bulletin.

SOIL AND PLOTS

The soil is designated by the Bureau of Soils, of the U. S. Department of Agriculture, as Cumberland loam. The surface soil is brownish-colored, 8-10 inches deep, of excellent texture, and underlain by a rather heavy dark-red subsoil, extending to a depth of probably 20 feet or more. The drainage is excellent. Prior to the experiments the land had been in grass for a number of years, and was in a state of high productivity for cereal crops, although it required liming for a crop like red clover. Tables 11 and 12 give chemical and mechanical analyses of this soil.

The plots were each 33 x 30 ft., or 1/40 acre, and were separated by a 2-ft. path. Diagram 1 shows their arrangement and the fertilizer and liming scheme.

CROPS AND SOIL MANAGEMENT

The first crop grown was cowpeas, in 1905. The application of lime was made after the disposal of this crop, but before the wheat seeding of that year. The liming was at the rate of 1,800 pounds per acre of burnt lime, and attention is called to the fact that reliming, which was at the rate of 1 ton per acre, was not made until 12 years later. On 14 plots the cowpea crops have been turned under as green manure, from 6 others they have been removed, and 1 plot has been kept in bare fallow during the summers. A few crop changes were necessitated. In 1917 spring oats were substituted for wheat, which was ruined by the unusually severe winter of 1916-1917; in 1919 soybeans were substituted for cowpeas; and in 1924 barley was substituted for wheat, due to a serious wheat disease which made its appearance in the crop harvested that year. The yields of both the oats and the barley, how-

ever, were calculated on the basis of 60 pounds per bushel, the same as the wheat.

| | Unlimed | Limed | Unlimed | Limed | Unlimed | Limed | Unlimed | Limed |
|---|------------------------------------|--------------|----------------------------------|------------------------------------|----------------------------------|-------|---------|-------|
| F | 8
P.K.(R.P.)
Peas
under | 7
Miscel. | 6
Manure
Peas
removed | 5
P.K.(A.P.)
Peas
under | 4
P.(A.P.)
Peas
removed | | | |
| G | 8
P.K.(R.P.)
Peas
removed | 7
Miscel. | 6
Manure
Peas
removed | 5
P.K.(A.P.)
Peas
removed | 4
P.(A.P.)
Peas
removed | | | |
| H | 8
P.K.(A.P.)
Peas
under | 7
Miscel. | 6
P.K.(B.M.)
Peas
under | 5
P.K.(A.P.)
No peas | 4
0
Peas
under | | | |
| I | 8
P.K.(R.P.)
Peas
under | 7
Miscel. | 6
P.K.(Slag)
Peas
under | 5
P.K.(A.P.)
Peas
under | 4
0
Peas
removed | | | |
| J | 8
K
Peas
under | 7
Miscel. | 6
P.K.(Slag)
Peas
under | 5
P.K.(R.P.)
Peas
under | 4
P.K.(B.M.)
Peas
under | | | |

Diagram 1—Experimental field, cowpea-wheat experiments—Knoxville

It should be stated that to prevent as far as possible the dislocation of the soil, reversals in the direction of both plowing and harrowing were made each year. Also the pea vines to be turned under were raked first away from the plow and then back into the open furrow, where they were covered at the next round. The result of these measures was to maintain marked uniformity of growth over every plot, and yearly the sharp definition between the plots grew more pronounced.

DATES OF PLANTING AND HARVESTING

The dates of planting wheat varied from October 9 to 25, with October 18 as the average. The dates of harvest varied from June 3 to 23, with June 12 as the average.

The dates of planting cowpeas varied from June 23 to July 15, with July 9 as the average. The hay crops were cut from September 8 to October 13, with September 23 as the average.

DISCUSSION OF THE PLOT DATA

Table 16 gives in detail the yields per acre of legume hay and the small grains for each plot, together with the fertilizer treatments, and the disposition of the legumes.

Table 1 presents a summary for the 20-year period of the average annual yields from the various plots, which are grouped so as to facilitate comparisons.

TABLE 1—Average annual yields per acre of (1) cowpea hay and (2) wheat under both limed and unlimed conditions for the 20-year period 1905-1925.

| Plot | Fertilizer | Disposition of cowpea crop | Cowpea hay | | | Wheat | | | | | |
|-----------------------------|------------|----------------------------|------------|----------|------------------------------|-------|-------|---------|-------|--------------------------|-------|
| | | | Limed | Un-limed | Average of limed and unlimed | Limed | | Unlimed | | Av. of limed and unlimed | |
| | | | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| H4 | None | Turned under | Tons | Tons | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons |
| J8 | K | " | 0.74 | 0.83 | 0.79 | 20.3 | 1.15 | 20.2 | 1.12 | 20.3 | 1.14 |
| J8 | K | " | 1.13 | 1.12 | 1.13 | 21.9 | 1.32 | 20.0 | 1.31 | 21.0 | 1.32 |
| F4 | P | " | 0.90 | 0.84 | 0.87 | 23.9 | 1.29 | 20.3 | 1.08 | 22.1 | 1.19 |
| F5 | PK | " | 1.17 | 1.08 | 1.12 | 24.7 | 1.39 | 23.9 | 1.34 | 24.3 | 1.37 |
| I5 | PK | " | 1.19 | 1.09 | 1.14 | 26.3 | 1.45 | 23.2 | 1.31 | 24.3 | 1.38 |
| Average of F5 and I5 | | | 1.18 | 1.09 | 1.13 | 25.5 | 1.42 | 23.6 | 1.33 | 24.6 | 1.39 |
| F8 | PK (R.P.) | Turned under | 1.08 | 1.10 | 1.09 | 27.0 | 1.60 | 26.4 | 1.62 | 26.7 | 1.61 |
| J5 | PK (R.P.) | " | 1.12 | 1.04 | 1.08 | 25.2 | 1.44 | 22.6 | 1.38 | 24.3 | 1.39 |
| I6 | PK (R.P.) | " | 1.11 | 0.99 | 1.05 | 28.8 | 1.44 | 21.7 | 1.29 | 22.8 | 1.37 |
| Average of F8, J5, and I8 | | | 1.10 | 1.04 | 1.07 | 25.3 | 1.49 | 23.6 | 1.41 | 24.6 | 1.46 |
| J4 | PK (B.M.) | Turned under | 1.10 | 1.03 | 1.07 | 23.3 | 1.45 | 21.5 | 1.30 | 22.3 | 1.42 |
| H6 | PK (B.M.) | " | 1.16 | 0.91 | 1.04 | 25.9 | 1.46 | 21.7 | 1.27 | 23.8 | 1.37 |
| Average of J4 and H6 | | | 1.13 | 0.97 | 1.06 | 24.6 | 1.46 | 21.6 | 1.29 | 23.3 | 1.40 |
| J6 | PK (T.S.) | Turned under | 1.07 | 0.99 | 1.03 | 24.9 | 1.54 | 21.9 | 1.37 | 23.4 | 1.46 |
| I6 | PK (T.S.) | " | 1.14 | 0.95 | 1.05 | 25.9 | 1.51 | 22.6 | 1.25 | 24.3 | 1.38 |
| Average of J6 and I6 | | | 1.11 | 0.97 | 1.04 | 25.4 | 1.53 | 22.3 | 1.31 | 23.9 | 1.42 |
| H5 | PK | No peas grown | | | | 18.7 | 1.04 | 15.5 | 0.98 | 17.1 | 0.98 |
| G4 | P | Removed | 0.70 | 0.58 | 0.64 | 17.2 | 0.89 | 13.3 | 0.69 | 15.3 | 0.79 |
| G5 | PK | " | 1.10 | 0.89 | 1.00 | 16.9 | 0.87 | 14.7 | 0.81 | 15.3 | 0.84 |
| G8 | PK (R.P.) | " | 1.04 | 0.92 | 0.98 | 16.1 | 0.79 | 15.3 | 0.79 | 15.7 | 0.79 |
| I4 | None | " | 0.60 | 0.55 | 0.58 | 13.6 | 0.69 | 10.4 | 0.60 | 12.0 | 0.64 |
| Average of G4, 5, 8, and I4 | | | 0.86 | 0.74 | 0.80 | 16.0 | 0.81 | 13.4 | 0.72 | 14.7 | 0.77 |
| F6 | Manure | Removed | 1.39 | 1.37 | 1.38 | 26.1 | 1.52 | 25.5 | 1.44 | 25.0 | 1.40 |
| G6 | Manure & P | " | 1.39 | 1.32 | 1.35 | 26.1 | 1.35 | 24.0 | 1.33 | 25.0 | 1.34 |
| Average of F6 and G6 | | | 1.39 | 1.35 | 1.37 | 26.1 | 1.44 | 24.8 | 1.39 | 25.4 | 1.41 |

Interpretation of symbols: R. P.—Rock phosphate; T. S.—Thomas slag phosphate;
B. M.—Bone meal; P.—Acid phosphate (unless otherwise specified);
K.—Muriate of potash.

RESPONSE TO POTASH

The yields from the 3 plots F4, G4, and H4, which received no potash, can be compared with those from the 3 plots F5, G5, and J8, which received annually 50 pounds of muriate of potash per acre, the treatments otherwise being the same in the 2 sets. The average annual increases per acre attributable to potash were as follows:

| | | Cowpea Hay | Wheat | |
|------------------------|----------------|------------|-----------|-----------|
| | | Lbs. | Grain Bu. | Straw Ton |
| Set 1—F5 | versus F4..... | 500 | 2.2 | 0.18 |
| Set 2—G5 | versus G4..... | 720 | 0.5 | 0.05 |
| Set 3—J8 | versus H4..... | 680 | 0.7 | 0.18 |
| Average increase | | 633 | 1.1 | 0.14 |

COMMENTS ON THE RESULTS

1. In each set the potash-treated plots produced materially more cowpea hay than the corresponding plots which received no potash. For the 20-year period the average annual gain attributable to potash amounted to 633 pounds of hay per acre. It is of interest to note that the gain was nearly as great in sets 1 and 3, where the cowpea crops were turned under, as in set 2, where the cowpea crops were removed.

2. The wheat crops were only slightly greater from the plots receiving potash; the average annual gain for the period being 1.1 bushels of grain and .14 ton of straw. Since in 2 of the 3 sets the cowpea crops were always turned under, this increase might well be due to the larger cowpea crops rather than to any direct influence of the added potash on wheat production.

EFFECTS OF LIMING AS INFLUENCED BY THE POTASH SUPPLY

Chart 1 shows the average annual yields of cowpea hay, under both the limed and unlimed conditions, from plots F4 and G4, which received no potash, compared with the averages from F5 and G5, which received each year 50 pounds of muriate of potash per acre. All the plots received an annual application of the same amount of acid phosphate and the disposal of the cowpea crops was the same for the 2 sets, the crops being turned under on F4 and F5 and removed from G4 and G5. Not only did the potash salt increase the yields of hay, but where it was used the effect of liming was much more pronounced. In fact, on this soil liming without potash was in every case of low effectiveness on the cow-

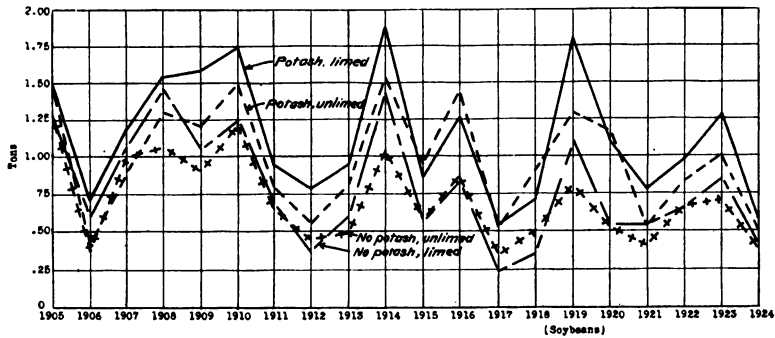


Chart 1—Effects of liming on the yields of cowpea hay as influenced by potash—Knoxville



Plot F6
Manure
Crops removed

Plot H4
No treatment
Crops turned under

Comparative growth of cowpea plants—1916 crop



Plot F4
Acid phosphate

Plot F5
Acid phosphate
Muriate of potash

Comparative growth of cowpea plants from plots where crops
were turned under—1916 crop



Plot I4
No treatment

Plot G4
Acid phosphate

Plot G5
Acid phosphate
Muriate of potash

Comparative growth of cowpea plants from plots where crops were
removed—1916 crop

pea crop, and there was no indication that it increased the availability of the soil potash. This conclusion is in harmony with the findings at this Station in lysimeter experiments with a soil of the same type, there being somewhat less potash in the drainage water from the limed tanks than from the unlimed.

With regard to the wheat crop, it is noticeable that, contrary to the results with cowpeas, liming was highly effective on plots F4 and G4.

POTASH IN RELATION TO PLANT DISEASES

In general the cowpea crops on the plots were considered good throughout the period. The plants were well inoculated from the outset, and there was little trouble from mildew or other disease, except in the case of the no-potash plots. On these plots not only were decreasing yields in evidence but the plants were frequently unhealthy, especially on the limed sections.

RESPONSE TO PHOSPHATING

The yields from the 3 plots H4, I4, and J8, which received no phosphate, can be compared with those from the 3 plots F4, G4, and F5, which received annual applications of phosphate, the treatments otherwise being the same for the two sets.

The average annual increases per acre attributable to phosphate were as follows:

| | Cowpea Hay | Wheat | |
|-------------------------|------------|--------------|--------------|
| | Lbs. | Grain
Bu. | Straw
Ton |
| Set 1—F4 versus H4..... | 160 | 1.8 | 0.05 |
| Set 2—F5 versus J8..... | 20 | 3.3 | 0.05 |
| Set 3—G4 versus I4..... | 120 | 3.3 | 0.15 |
| Average increase | 87 | 2.8 | 0.08 |

The phosphate applications failed to produce marked returns in the yield of cowpea hay, the average annual increase being only 87 pounds per acre. On the other hand, the increase in the yield of wheat was considerable, amounting to an annual average of 2.8 bushels per acre.

POTASH VERSUS PHOSPHATE

The effects of potash and phosphate on the two crops were decidedly different. The former increased in particular the yield of cowpea hay, while the latter increased the yield of wheat. These results are in harmony with the general findings in field trials on soils only moderately deficient in these two elements of plant food.

¹MacIntire, W. H., Shaw, W. M., and Young, J. B. A 5-year lysimeter study of the supposed liberation of soil potassium by calcic and magnesian additions. *Soil Sci.* 16: 4. Oct. 1923.

THE COMPARATIVE VALUES OF DIFFERENT PHOSPHATES

At the outset of the experiments it was hoped that material differences between the results from different phosphates would appear in the crop yields. But the yields obtained were so nearly alike that distinctions cannot be made with certainty. In fact, the differences found would not have been unexpected had only one kind of phosphate been used throughout at a constant rate, for no



Plot F4—fertilized with phosphate only



Plot F5—fertilized with phosphate and potash

Effects of potash on growth of cowpeas—1920 crop

In spite of the soil deficiency in potash, which became increasingly evident in the cowpea crop, the effect was scarcely discernible in the yields of wheat

two plots can be counted upon to have exactly the same natural productivity, and some allowance for such inequality must be made even where several are averaged. A soil highly responsive to phosphating is a prime essential to a satisfactory comparison of this kind.

FARMYARD MANURE

In the case of the 2 plots F6 and G6 the cowpea crops were removed, but 4 tons per acre of good-quality farmyard manure from the general farm pit was applied annually.

EFFECT ON CROP YIELDS

The yields were uniformly high, and in the case of the cowpea crop were appreciably larger than those obtained under any other condition. The average annual yield of cured hay per acre for the 20-year period was 1.37 tons. This was 520 pounds more than that from plots F5 and F8, fertilized with phosphate and potash, where the cowpea crops were turned under, and 760 pounds more than the average from G5 and G8, fertilized the same as F5 and F8, but having the cowpea crops removed annually. The average grain yield from F6 and G6 was 25.4 bushels. This was identical with that from F5 and F8, and 9.6 bushels larger than the average from G5 and G8. Tables 2, 3, and 4 give the data, and charts 2 and 3 present graphically the yields obtained annually under each of these 3 conditions. The charts show that the yields of cowpea hay were well maintained throughout the period in all cases, but that there was a continued downward tendency in wheat yield even under the most favorable conditions.

TABLE 2—Average annual yields per acre of crops grown on plots F6 and G6, which received 4 tons of manure each year—(all crops removed annually).

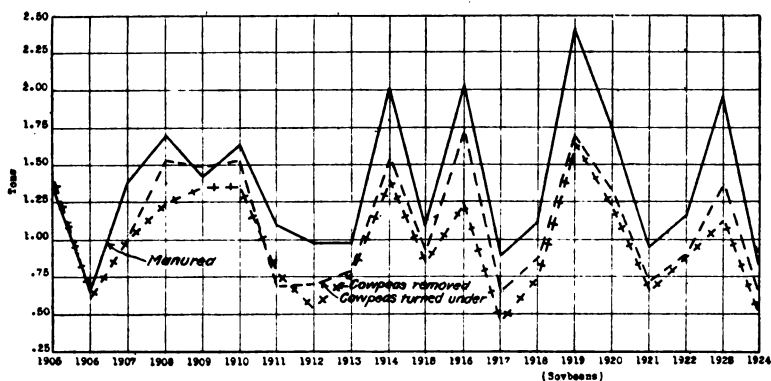
| Year | Cowpea hay | | | Wheat | | | | | |
|---------|------------|----------|------------------------------|--------|--------|---------|--------|------------------------------|-------|
| | Limed | Un-limed | Average of limed and unlimed | Limed | | Unlimed | | Average of limed and unlimed | |
| | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| | Tons | Tons | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons |
| 1905-6 | (1.35) | (1.35) | 1.35 | (37.0) | (2.00) | (37.0) | (2.00) | 37.0 | 2.00 |
| 1906-7 | 0.67 | 0.67 | 0.67 | 29.0 | 1.85 | 31.5 | 1.83 | 30.3 | 1.87 |
| 1907-8 | 1.41 | 1.37 | 1.39 | 24.0 | 1.30 | 21.9 | 1.23 | 23.0 | 1.27 |
| 1908-9 | 1.78 | 1.60 | 1.69 | 23.5 | 1.48 | 22.5 | 1.36 | 23.0 | 1.42 |
| 1909-10 | 1.48 | 1.37 | 1.43 | 27.5 | 1.79 | 26.7 | 1.81 | 27.1 | 1.80 |
| 1910-11 | 1.68 | 1.58 | 1.63 | 24.4 | 1.33 | 24.2 | 1.35 | 24.3 | 1.34 |
| 1911-12 | 1.20 | 0.99 | 1.10 | 34.0 | 1.78 | 31.0 | 1.71 | 32.5 | 1.75 |
| 1912-13 | 0.94 | 1.02 | 0.98 | 32.5 | 1.80 | 27.8 | 1.80 | 30.2 | 1.80 |
| 1913-14 | 0.98 | 0.96 | 0.97 | 27.6 | 1.36 | 25.3 | 1.37 | 26.5 | 1.37 |
| 1914-15 | 1.99 | 2.06 | 2.02 | 23.3 | 1.14 | 22.9 | 1.08 | 23.1 | 1.11 |
| 1915-16 | 0.89 | 1.26 | 1.08 | 23.6 | 1.32 | 22.7 | 1.32 | 23.2 | 1.32 |
| 1916-17 | 2.02 | 2.04 | 2.03 | 28.4 | 0.70 | 26.7 | 0.70 | 27.6 | 0.70 |
| 1917-18 | 1.02 | 0.78 | 0.90 | 24.7 | 1.22 | 20.6 | 1.14 | 22.7 | 1.18 |
| 1918-19 | 1.15 | 1.09 | 1.12 | 21.5 | 1.66 | 20.5 | 1.55 | 21.0 | 1.61 |
| 1919-20 | 2.64 | 2.17 | 2.41 | 21.9 | 1.33 | 20.5 | 1.24 | 21.2 | 1.29 |
| 1920-21 | 1.64 | 1.84 | 1.74 | 26.7 | 1.65 | 26.7 | 1.60 | 26.7 | 1.63 |
| 1921-22 | 0.98 | 0.91 | 0.95 | 17.7 | 1.53 | 16.4 | 1.34 | 17.1 | 1.44 |
| 1922-23 | 1.18 | 1.16 | 1.17 | 22.7 | 1.40 | 20.7 | 1.28 | 21.7 | 1.34 |
| 1923-24 | 1.92 | 1.79 | 1.86 | 21.7 | 1.35 | 20.7 | 1.34 | 21.2 | 1.35 |
| 1924-25 | 0.82 | 0.83 | 0.83 | 32.7 | 0.72 | 30.2 | 0.70 | 31.5 | 0.71 |
| Average | 1.39 | 1.34 | 1.37 | 26.2 | 1.44 | 24.8 | 1.39 | 25.5 | 1.42 |

TABLE 3—Average annual yields per acre of crops grown on plots F5 and F8—cowpea crops turned under—phosphate and potash applications the same as for G5 and G8, where cowpea crops were removed.

| Year | Cowpea hay | | | Wheat | | | | | |
|---------|----------------|----------------|------------------------------|---------------|----------------|---------------|----------------|------------------------------|--------------|
| | Limed | Un-limed | Average of limed and unlimed | Limed | | Unlimed | | Average of limed and unlimed | |
| | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| | Tons
(1.43) | Tons
(1.43) | Tons
1.43 | Bu.
(35.8) | Tons
(2.15) | Bu.
(35.8) | Tons
(2.15) | Bu.
35.8 | Tons
2.15 |
| 1905-6 | 0.67 | 0.67 | 0.62 | 31.1 | 2.31 | 30.9 | 2.14 | 31.0 | 2.23 |
| 1906-7 | 1.00 | 1.02 | 1.01 | 29.0 | 1.55 | 25.1 | 1.43 | 27.1 | 1.49 |
| 1907-8 | 1.55 | 1.50 | 1.53 | 27.2 | 1.75 | 26.7 | 1.70 | 27.0 | 1.73 |
| 1908-9 | 1.59 | 1.38 | 1.49 | 28.2 | 1.93 | 27.8 | 1.75 | 27.8 | 1.84 |
| 1909-10 | 1.59 | 1.47 | 1.53 | 29.2 | 1.65 | 26.7 | 1.61 | 28.0 | 1.63 |
| 1910-11 | 0.68 | 0.69 | 0.69 | 31.9 | 1.67 | 31.4 | 1.70 | 31.7 | 1.69 |
| 1911-12 | 0.86 | 0.66 | 0.71 | 29.8 | 1.71 | 27.8 | 1.74 | 28.8 | 1.73 |
| 1912-13 | 0.80 | 0.80 | 0.80 | 26.8 | 1.46 | 25.2 | 1.51 | 26.0 | 1.49 |
| 1913-14 | 1.61 | 1.48 | 1.55 | 23.6 | 1.26 | 23.2 | 1.13 | 23.4 | 1.20 |
| 1914-15 | 0.86 | 0.98 | 0.92 | 22.2 | 1.23 | 21.9 | 1.23 | 22.1 | 1.23 |
| 1915-16 | 1.65 | 1.83 | 1.74 | 20.8 | 0.82 | 27.2 | 0.73 | 23.7 | 0.78 |
| 1916-17 | 0.66 | 0.65 | 0.66 | 25.7 | 1.48 | 19.0 | 1.14 | 22.4 | 1.31 |
| 1917-18 | 0.73 | 1.02 | 0.88 | 23.2 | 1.53 | 22.2 | 1.32 | 22.7 | 1.43 |
| 1918-19 | 1.92 | 1.44 | 1.69 | 23.9 | 1.34 | 22.1 | 1.35 | 23.0 | 1.35 |
| 1919-20 | 1.24 | 1.37 | 1.32 | 26.4 | 1.75 | 26.8 | 1.95 | 26.6 | 1.85 |
| 1920-21 | 0.76 | 0.67 | 0.72 | 17.2 | 1.43 | 16.2 | 1.40 | 16.7 | 1.42 |
| 1921-22 | 0.92 | 0.89 | 0.91 | 20.2 | 1.36 | 22.9 | 1.56 | 21.6 | 1.46 |
| 1922-23 | 1.39 | 1.34 | 1.37 | 18.3 | 1.13 | 18.4 | 1.15 | 18.4 | 1.14 |
| 1923-24 | 0.61 | 0.66 | 0.64 | 26.7 | 0.63 | 26.5 | 0.62 | 26.6 | 0.63 |
| 1924-25 | 1.13 | 1.09 | 1.11 | 25.8 | 1.51 | 25.2 | 1.47 | 25.5 | 1.49 |
| Average | | | | | | | | | |

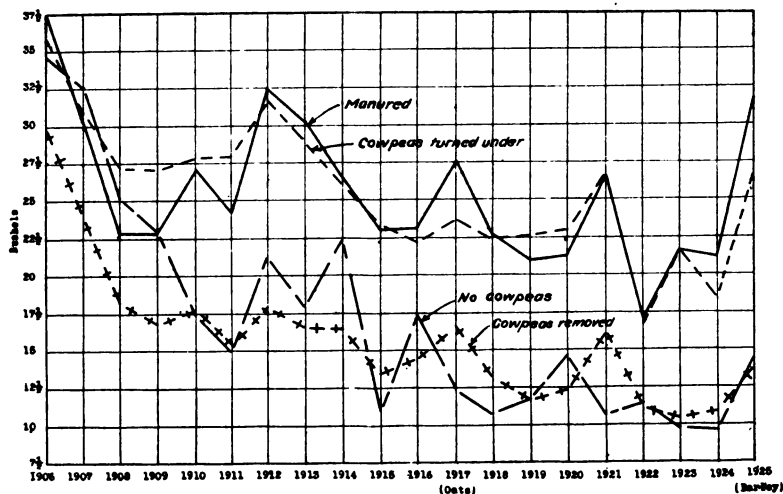
TABLE 4—Average annual yields per acre of crops grown on plots G5 and G8—cowpea crops removed as hay—phosphate and potash applications the same as for F5 and F8, where cowpea crops were turned under.

| Year | Cowpea hay | | | Wheat | | | | | |
|---------|------------|----------|------------------------------|-------|-------|---------|-------|------------------------------|-------|
| | Limed | Un-limed | Average of limed and unlimed | Limed | | Unlimed | | Average of limed and unlimed | |
| | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| | Tons | Tons | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons |
| 1906-7 | 0.76 | 0.45 | 0.61 | 23.0 | 1.25 | 21.2 | 1.35 | 22.1 | 1.30 |
| 1907-8 | 1.07 | 0.94 | 1.01 | 21.2 | 1.05 | 16.4 | 0.87 | 18.8 | 0.96 |
| 1908-9 | 1.26 | 1.24 | 1.25 | 16.9 | 1.04 | 16.8 | 0.97 | 16.9 | 1.01 |
| 1909-10 | 1.48 | 1.22 | 1.35 | 19.9 | 1.09 | 15.5 | 0.94 | 17.7 | 1.02 |
| 1910-11 | 1.47 | 1.25 | 1.36 | 16.4 | 0.79 | 14.2 | 0.72 | 15.3 | 0.76 |
| 1911-12 | 0.88 | 0.68 | 0.78 | 17.5 | 0.80 | 18.3 | 0.85 | 17.9 | 0.83 |
| 1912-13 | 0.60 | 0.58 | 0.59 | 16.5 | 0.76 | 16.6 | 0.73 | 16.6 | 0.77 |
| 1913-14 | 0.81 | 0.72 | 0.77 | 17.0 | 0.89 | 16.0 | 0.88 | 16.5 | 0.89 |
| 1914-15 | 1.58 | 1.19 | 1.39 | 15.2 | 0.59 | 12.5 | 0.58 | 13.9 | 0.59 |
| 1915-16 | 0.58 | 0.79 | 0.64 | 14.5 | 0.70 | 14.5 | 0.72 | 14.5 | 0.71 |
| 1916-17 | 1.28 | 1.17 | 1.23 | 17.2 | 0.43 | 16.2 | 0.47 | 16.7 | 0.48 |
| 1917-18 | 0.45 | 0.45 | 0.45 | 16.6 | 0.80 | 9.7 | 0.50 | 13.2 | 0.65 |
| 1918-19 | 0.67 | 0.80 | 0.74 | 11.2 | 0.67 | 11.9 | 0.75 | 11.6 | 0.71 |
| 1919-20 | 2.02 | 1.25 | 1.64 | 12.8 | 0.74 | 12.0 | 0.67 | 12.4 | 0.71 |
| 1920-21 | 1.15 | 1.24 | 1.20 | 16.2 | 0.95 | 16.2 | 1.05 | 16.2 | 1.00 |
| 1921-22 | 0.74 | 0.56 | 0.65 | 11.2 | 0.75 | 10.9 | 0.80 | 11.1 | 0.78 |
| 1922-23 | 0.99 | 0.81 | 0.90 | 11.2 | 0.71 | 9.5 | 0.66 | 10.4 | 0.69 |
| 1923-24 | 1.31 | 0.95 | 1.13 | 11.0 | 0.62 | 10.7 | 0.59 | 10.9 | 0.61 |
| 1924-25 | 0.57 | 0.42 | 0.50 | 14.7 | 0.39 | 11.6 | 0.85 | 13.2 | 0.37 |
| Average | 1.07 | 0.91 | 0.99 | 16.5 | 0.83 | 15.0 | 0.80 | 15.8 | 0.82 |



- Plots F6, G6—Cowpeas removed as hay; 4 tons per acre manure applied annually.
- - - Plots F5, F8—Cowpeas turned under annually; acid phosphate and muriate of potash used as fertilizers.
- + + + + + Plots G5, G8—Cowpeas removed as hay annually; fertilized same as F5 and F8.

Chart 2—Yields of cowpea hay under various conditions—Knoxville



- Plots F6, G6—Received 4 tons manure per acre annually; cowpea crops removed as hay.
- - - Plots F5, F8—Wheat after cowpea crops turned under; fertilized same as H5.
- - - Plot H5—Wheat after summer fallow; acid phosphate and muriate of potash used as fertilizers.
- + + + + + Plots G5, G8—Wheat after cowpeas removed as hay; fertilized same as H5.

Chart 3—Yields of wheat under various conditions—Knoxville

MONEY VALUE

The money value of a ton of manure in farm practice is of interest. It will, of course, vary with a number of conditions, such as the nature of the soil and the kind of crop. In this case the value is high, as may be seen if the returns from F6 and G6 be compared with those from G5 and G8. Assigning to the crops the rather high average prices of \$20.00 per ton for the hay and \$1.50 per bushel for the wheat, each ton of manure gave crop increases worth \$5.50. This, of course, is not all profit, because the cost of hauling and spreading the manure and the extra cost of harvesting and marketing the increased crops are not included. On the other hand, the manure supplied the phosphate and potash requirements of this soil, so that an annual saving of \$3.50 per acre could be allowed as the approximate cost of the fertilizer applications made to G5 and G8.

FOR WHICH CROP SHOULD THE MANURE BE APPLIED?

Beginning in 1911 and continuing to the end of the 20-year period, in 1925, the yearly application of manure was made to one plot prior to its preparation for the cowpea crop and to the other plot just before the preparation for the wheat crop. To avoid possible error due to inequality in soil fertility, the applications were alternated from year to year. That is, if the manure was applied for the cowpea crop on F6, for example, none was applied to G6 until the time of preparation for the wheat; and the next year the procedure was reversed. There was a minor irregularity in the carrying out of this plan, and as a result only 13 crops of cowpea hay and the same number of crops of wheat can be included under each condition. Twelve of the manured cowpea crops were superior to the unmanured, the average yearly production being 1.46 tons per acre for the manured crops and 1.20 tons for the unmanured. In the case of the wheat, while the results from 10 of the 13 crops were favorable to the manured, the average annual acre gain was only 1.6 bushels of grain and .15 ton of straw.

The data are therefore very favorable to the application of the manure prior to the cowpea crop rather than the wheat crop.

NITROGEN RECOVERY

The average nitrogen content of the manure used was found to be .73 per cent. The amount of nitrogen furnished annually by the 4-ton application was therefore 58.4 pounds per acre. Nitrogen determinations were made frequently in the case of the

wheat crops and occasionally for the cowpea crops. The averages found were 2.11 per cent for the wheat grain and .46 per cent for wheat straw, and 2.45 per cent for the cowpea hay. With these figures as the basis, it was calculated that there were removed annually from the manure plots 18.44 pounds per acre more of nitrogen in the grain and straw of the wheat and 18.62 pounds more in the cowpea hay than in the crops grown on plots G5 and G8, which received only phosphate and potash. Both crops considered, there was therefore an apparent recovery of 63.4 per cent of the nitrogen of the manure applied. This is a rather high figure, and it is probable that the actual recovery was somewhat less, as there were larger residues of fallen leaves, roots, and stubble in the case of the manure plots than in the case of plots G5 and G8.

LIMING

As may be seen by inspection of table 1, superior yields on the limed sections are the rule, but are more noticeable for the wheat than for the cowpea crop. The effects of liming will now be discussed more fully in connection with a consideration of the annual fluctuations in yield.

TABLE 5—Average annual yields from all plots, except H8, of (1) cowpea hay and (2) wheat, under both limed and unlimed conditions.

| Year | Cowpea hay | | | Wheat | | | | | |
|---------|----------------|----------------|------------------------------|---------------|----------------|---------------|----------------|------------------------------|--------------|
| | Limed | Unlimed | Average of limed and unlimed | Limed | | Unlimed | | Average of limed and unlimed | |
| | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| 1905-6 | Tons
(1.36) | Tons
(1.36) | Tons
1.36 | Bu.
(33.1) | Tons
(2.04) | Bu.
(33.1) | Tons
(2.04) | Bu.
33.1 | Tons
2.04 |
| 1906-7 | 0.69 | 0.55 | 0.62 | 30.6 | 1.94 | 27.8 | 1.75 | 29.2 | 1.85 |
| 1907-8 | 1.10 | 1.01 | 1.06 | 25.9 | 1.38 | 22.2 | 1.24 | 24.1 | 1.31 |
| 1908-9 | 1.59 | 1.30 | 1.45 | 24.2 | 1.60 | 22.8 | 1.44 | 23.5 | 1.52 |
| 1909-10 | 1.51 | 1.34 | 1.43 | 26.1 | 1.73 | 22.1 | 1.48 | 24.1 | 1.61 |
| 1910-11 | 1.53 | 1.36 | 1.45 | 24.0 | 1.33 | 21.2 | 1.17 | 22.6 | 1.25 |
| 1911-12 | 0.85 | 0.76 | 0.81 | 26.6 | 1.40 | 24.0 | 1.32 | 25.3 | 1.36 |
| 1912-13 | 0.70 | 0.52 | 0.61 | 25.3 | 1.37 | 22.8 | 1.30 | 23.8 | 1.34 |
| 1913-14 | 0.73 | 0.69 | 0.71 | 23.2 | 1.22 | 21.7 | 1.20 | 22.5 | 1.21 |
| 1914-15 | 1.52 | 1.26 | 1.39 | 20.3 | 0.99 | 17.4 | 0.89 | 18.9 | 0.94 |
| 1915-16 | 0.79 | 0.85 | 0.82 | 19.6 | 1.02 | 19.1 | 1.03 | 19.4 | 1.03 |
| 1916-17 | 1.40 | 1.39 | 1.40 | 20.6 | 0.56 | 20.1 | 0.59 | 20.4 | 0.58 |
| 1917-18 | 0.59 | 0.54 | 0.57 | 20.6 | 1.12 | 12.6 | 0.75 | 16.6 | 0.94 |
| 1918-19 | 0.65 | 0.52 | 0.74 | 16.7 | 1.13 | 16.4 | 1.17 | 16.6 | 1.15 |
| 1919-20 | 1.77 | 1.47 | 1.62 | 19.2 | 1.16 | 16.7 | 1.00 | 18.0 | 1.08 |
| 1920-21 | 1.08 | 1.15 | 1.12 | 22.7 | 1.43 | 21.8 | 1.41 | 22.3 | 1.45 |
| 1921-22 | 0.71 | 0.62 | 0.67 | 14.5 | 1.19 | 13.1 | 1.11 | 13.8 | 1.15 |
| 1922-23 | 0.88 | 0.84 | 0.86 | 16.7 | 1.20 | 15.3 | 1.12 | 16.3 | 1.16 |
| 1923-24 | 1.25 | 1.11 | 1.18 | 16.1 | 1.00 | 15.1 | 0.92 | 15.6 | 0.96 |
| 1924-25 | 0.57 | 0.56 | 0.57 | 22.5 | 0.56 | 18.0 | 0.48 | 20.3 | 0.52 |
| Average | 1.06 | 0.98 | 1.02 | 22.4 | 1.27 | 20.2 | 1.17 | 21.3 | 1.22 |

THE EFFECTS OF LIMING ON THE YIELD OF COWPEAS

Chart 4 was made from data contained in table 5, and gives a graphic comparison between the annual yields of cowpea hay obtained under limed and unlimed conditions. The yields for each year are averages from 18 plots, or all except H8, without regard to fertilizer treatment. Since there were 4 replications of limed and unlimed sections, with 4 or 5 plots in each, the data are considered to be especially dependable.

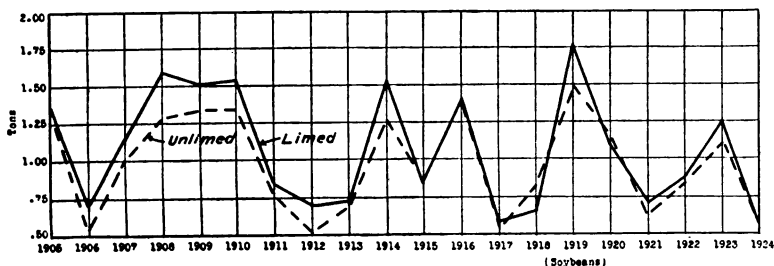


Chart 4—Yields of cowpea hay under limed and unlimed conditions—all plots included except H8—Knoxville

The results may be summarized as follows:

The limed sections produced more than the unlimed for each year of the period 1906-1914. The average annual increase for the 9 years was 318 pounds of hay per acre. For the next 3 years the yields were practically identical. The second application of lime was made in the summer of 1917, just prior to the seeding of the cowpea crop. For the following 8 crops a light average increase in hay production was obtained from the limed sections, but in 1918 and 1920 the unlimed sections outyielded the limed, and in 1917 and 1925 the yields were practically identical. In 1919 it was found necessary to substitute soybeans for cowpeas. The soybean crop was large and the effects of liming were plainly evident, both in the appearance of the growing plants and in the yields of hay obtained. With this crop included, the limed sections averaged for the last 7 years 96 pounds more hay per acre than the unlimed; but without it there was on the average for the 6 cowpea crops a negligible difference of only 14 pounds per acre in favor of the limed sections. In this connection it should be stated that in 1917, the first year after reliming, a poor stand of cowpeas was obtained on all the limed sections, due, it appeared, to the noticeably drier and more flocculated soil condition of those sections. The growth and color of the plants indicated that there would have been no reduction in yield as a result of liming had

there been a good stand. From any point of view, however, it is evident that the second liming produced decidedly less effect on the cowpea crops than the first liming.

EFFECTS OF LIMING ATTRIBUTABLE TO INCREASED AVAILABILITY OF SOIL NITROGEN

Consideration of the effects of liming on the cowpea crops under the various conditions furnishes strong evidence that an in-

TABLE 6—Average annual yields per acre of crops grown on plots G4, G5, G8, and I4—cowpea crops removed as hay—fertilizer treatments the same as for plots F4, F5, F8, and H4, where cowpea crops were turned under.

| Year | Cowpea hay | | | Wheat | | | | | |
|---------|------------|----------|------------------------------|--------|--------|---------|--------|------------------------------|-------|
| | Limed | Un-limed | Average of limed and unlimed | Limed | | Unlimed | | Average of limed and unlimed | |
| | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| 1905-6 | (1.40) | (1.40) | 1.40 | (29.4) | (1.48) | (29.4) | (1.48) | 29.4 | 1.48 |
| 1905-6 | (1.33) | (1.33) | 1.33 | (28.9) | (1.50) | (28.9) | (1.50) | 28.9 | 1.50 |
| 1906-7 | 0.70 | 0.42 | 0.56 | 25.1 | 1.37 | 21.4 | 1.24 | 23.3 | 1.31 |
| 1907-8 | 0.98 | 0.86 | 0.92 | 22.1 | 1.10 | 16.2 | 0.88 | 19.2 | 0.99 |
| 1908-9 | 1.29 | 1.08 | 1.19 | 18.1 | 1.09 | 16.8 | 0.97 | 17.5 | 1.03 |
| 1909-10 | 1.22 | 0.96 | 1.09 | 19.2 | 1.11 | 13.7 | 0.87 | 16.5 | 0.99 |
| 1910-11 | 1.25 | 1.12 | 1.19 | 15.9 | 0.76 | 11.7 | 0.60 | 13.8 | 0.68 |
| 1911-12 | 0.71 | 0.57 | 0.64 | 16.4 | 0.76 | 13.8 | 0.68 | 15.2 | 0.72 |
| 1912-13 | 0.48 | 0.45 | 0.47 | 15.9 | 0.77 | 14.6 | 0.74 | 15.3 | 0.76 |
| 1913-14 | 0.64 | 0.54 | 0.59 | 17.9 | 0.88 | 16.4 | 0.84 | 17.2 | 0.86 |
| 1914-15 | 1.25 | 0.88 | 1.07 | 12.9 | 0.54 | 10.7 | 0.49 | 11.8 | 0.51 |
| 1915-16 | 0.63 | 0.59 | 0.61 | 14.2 | 0.70 | 14.2 | 0.70 | 14.2 | 0.70 |
| 1916-17 | 0.99 | 0.90 | 0.95 | 16.6 | 0.41 | 18.6 | 0.39 | 15.1 | 0.40 |
| 1917-18 | 0.30 | 0.33 | 0.32 | 14.0 | 0.70 | 07.4 | 0.37 | 10.7 | 0.53 |
| 1918-19 | 0.47 | 0.60 | 0.54 | 10.3 | 0.58 | 10.4 | 0.65 | 10.4 | 0.62 |
| 1919-20 | 1.52 | 1.08 | 1.28 | 11.7 | 0.73 | 09.9 | 0.59 | 10.8 | 0.66 |
| 1920-21 | 1.43 | 1.63 | 1.53 | 14.5 | 0.80 | 18.4 | 0.80 | 14.0 | 0.80 |
| 1921-22 | 0.51 | 0.43 | 0.47 | 10.9 | 0.79 | 09.9 | 0.73 | 10.4 | 0.76 |
| 1922-23 | 0.77 | 0.66 | 0.72 | 10.2 | 0.67 | 08.2 | 0.58 | 09.2 | 0.63 |
| 1923-24 | 0.97 | 0.75 | 0.86 | 10.3 | 0.57 | 08.8 | 0.52 | 09.6 | 0.54 |
| 1924-25 | 0.43 | 0.37 | 0.40 | 14.0 | 0.37 | 08.5 | 0.32 | 11.3 | 0.35 |
| Average | 0.89 | 0.78 | 0.84 | 16.0 | 0.81 | 13.4 | 0.72 | 14.7 | 0.77 |

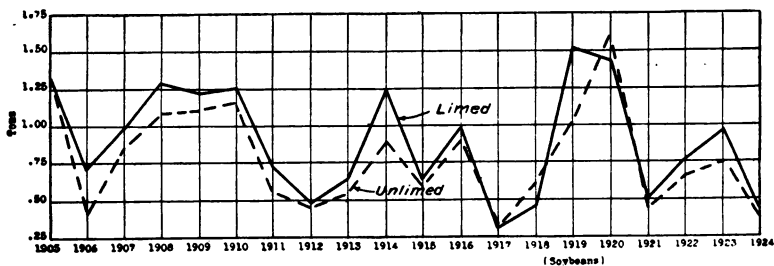


Chart 5—Yields of cowpea hay from limed and unlimed sections of plots G4, G5, G8 and I4 (averaged)—hay crops removed annually—Knoxville

creased supply of available nitrogen was the reason for the generally increased yields on the limed sections. Chart 5, prepared from table 6, shows the average annual yields from the limed and unlimed sections of the 4 plots G4, G5, G8, and I4, where all cowpea crops were removed. Chart 6, prepared from table 7, depicts in like manner the yields from the 4 corresponding plots, F4, F5, F8, and H4, where all the cowpea crops were turned under. From

TABLE 7—Average annual yields per acre of crops grown on plots F4, F5, F8, and H4—cowpea crops turned under—fertilizer treatments the same as for plots G4, G5, G8, and I4, where cowpea crops were removed as hay.

| Year | Cowpea hay | | | Wheat | | | | | |
|---------|-------------|-------------|------------------------------|------------|-------------|------------|-------------|------------------------------|-----------|
| | Limed | Unlimed | Average of limed and unlimed | Limed | | Unlimed | | Average of limed and unlimed | |
| | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| 1905-6 | Tons (1.32) | Tons (1.32) | Tons 1.32 | Bu. (35.2) | Tons (2.10) | Bu. (35.2) | Tons (2.10) | Bu. 35.2 | Tons 2.10 |
| 1906-7 | 0.62 | 0.51 | 0.57 | 32.0 | 2.19 | 28.7 | 1.78 | 30.4 | 1.99 |
| 1907-8 | 1.00 | 1.01 | 1.01 | 28.5 | 1.49 | 23.6 | 1.27 | 26.1 | 1.38 |
| 1908-9 | 1.51 | 1.42 | 1.47 | 26.9 | 1.76 | 24.3 | 1.54 | 25.6 | 1.65 |
| 1909-10 | 1.40 | 1.26 | 1.33 | 27.2 | 1.85 | 25.2 | 1.64 | 26.2 | 1.75 |
| 1910-11 | 1.44 | 1.30 | 1.37 | 28.2 | 1.59 | 25.1 | 1.43 | 26.7 | 1.51 |
| 1911-12 | 0.71 | 0.73 | 0.72 | 29.9 | 1.49 | 28.8 | 1.48 | 29.4 | 1.46 |
| 1912-13 | 0.67 | 0.53 | 0.60 | 26.4 | 1.43 | 24.6 | 1.48 | 25.5 | 1.46 |
| 1913-14 | 0.70 | 0.68 | 0.69 | 25.5 | 1.36 | 24.5 | 1.39 | 25.0 | 1.38 |
| 1914-15 | 1.52 | 1.35 | 1.49 | 21.6 | 1.09 | 21.0 | 1.01 | 21.3 | 1.05 |
| 1915-16 | 0.76 | 0.88 | 0.82 | 21.2 | 1.09 | 21.5 | 1.16 | 21.4 | 1.12 |
| 1916-17 | 1.34 | 1.46 | 1.40 | 18.1 | 0.53 | 23.3 | 0.72 | 21.2 | 0.63 |
| 1917-18 | 0.48 | 0.55 | 0.52 | 22.6 | 1.20 | 16.0 | 0.92 | 19.3 | 1.06 |
| 1918-19 | 0.57 | 0.79 | 0.68 | 18.5 | 1.22 | 17.7 | 1.09 | 18.1 | 1.16 |
| 1919-20 | 1.48 | 1.30 | 1.39 | 20.8 | 1.18 | 19.4 | 1.17 | 19.9 | 1.18 |
| 1920-21 | 0.90 | 1.03 | 0.97 | 23.5 | 1.43 | 24.1 | 1.63 | 23.8 | 1.53 |
| 1921-22 | 0.67 | 0.59 | 0.63 | 15.9 | 1.27 | 14.4 | 1.25 | 15.2 | 1.26 |
| 1922-23 | 0.78 | 0.84 | 0.81 | 18.2 | 1.28 | 18.7 | 1.30 | 18.5 | 1.29 |
| 1923-24 | 1.09 | 1.10 | 1.10 | 17.2 | 1.02 | 17.3 | 1.01 | 17.3 | 1.02 |
| 1924-25 | 0.51 | 0.54 | 0.53 | 22.7 | 0.57 | 20.7 | 0.53 | 21.7 | 0.55 |
| Average | 0.97 | 0.96 | 0.97 | 24.0 | 1.36 | 22.7 | 1.29 | 23.4 | 1.33 |

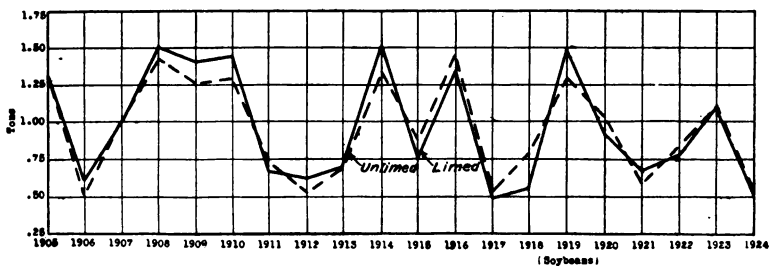


Chart 6—Yields of cowpea hay from limed and unlimed sections of plots F4, F5, F8 and H4 (averaged)—cowpea crops turned under each year—Knoxville

inspection of these two charts it is evident that the effects of liming are much more pronounced where the cowpea crops were removed. In fact, after the eighth season, 1912, there is no practical difference between the yields on the limed and unlimed sections of the plots where the peas were turned under. Chart 7 indicates that liming was of minor importance in the case of the manure plots, the record in this respect closely paralleling that of chart

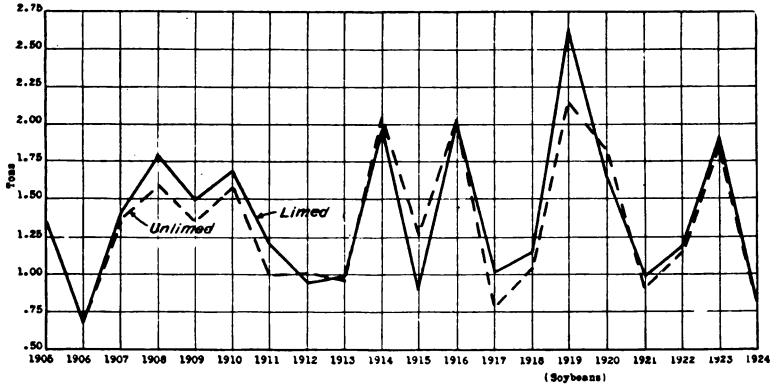


Chart 7—Yields of cowpea hay from limed and unlimed sections of plots receiving 4 tons of manure per acre annually—yields from plots F6 and G6 (averaged)—Knoxville.

6. Chart 8, recording the yields of plot H8, where no wheat was grown and where the cowpea crops were turned under, gives no conclusive evidence that the crops were affected by the limings. As a rule the variations were so small as to be attributable to minor factors which characterize work of this kind. To summarize,

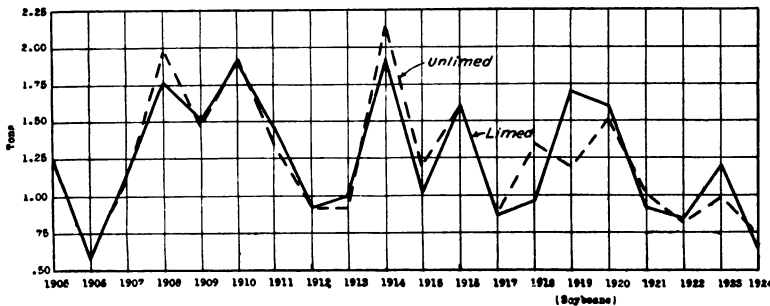


Chart 8—Yields of cowpea hay, plot H8—crops turned under—no wheat grown—liming not effective—Knoxville

liming has evidently increased the cowpea crop most where there was the least replacement of soil nitrogen and was of little consequence with a good supply of nitrogen.

This evidence is substantiated by the soil nitrogen data, which will be given later; also by the following observations:

In the early years there was a noticeable difference between the nodule development on the cowpea roots from the limed and unlimed sections. In the latter case the nodules were appreciably larger and more numerous than in the former. This is of interest because sparse and small nodules on cowpea roots are characteristic when the soil is rich in nitrogen. Also in the early years the leaves of the cowpea plants of the limed sections were both of much darker green color and had a higher nitrogen content than those of the unlimed. In 1907, for example, the average nitrogen content of the cowpea hay from 9 plots was 2.44 per cent for the limed sections and 2.17 per cent for the unlimed.

THE EFFECTS OF LIMING ON THE YIELD OF WHEAT

Chart 9 presents graphically the annual average yields of wheat from all plots under both the limed and the unlimed condition. Liming resulted in markedly superior yields throughout the first 10 years, with an average increase for the years 1907-1915 of 2.7 bushels of grain per acre. This period was followed by two years,

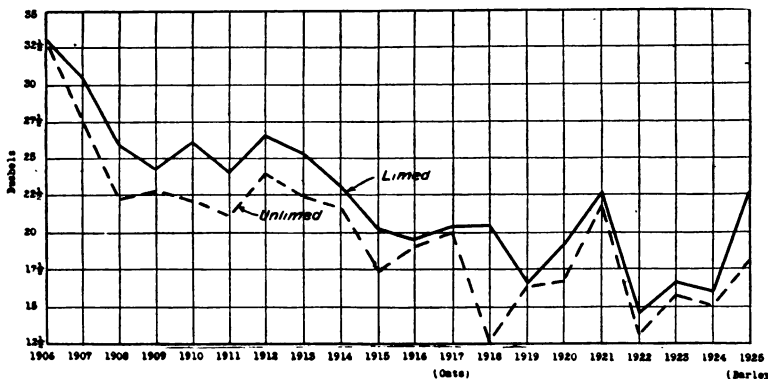


Chart 9—Yields of wheat from limed and unlimed sections (all plots averaged)—1918 crop the first after reliming—Knoxville

1916 and 1917, in which the yields on the limed and unlimed sections were practically equal. Following the second liming, the limed sections produced a much larger crop in 1918 than the unlimed, and for the next 7 years continued to produce, with one exception, consistently larger crops. The average difference for



Limed section

Unlimed section

Effect of liming on soil moisture (photographed in March 1926)

The division between the limed and unlimed sections was at times sharply defined by a difference in soil moisture; the surface soil of the unlimed area being appreciably more moist, and hence darker-colored, than the limed.

the last 7 years was 1.6 bushels of grain per acre. Attention is called to the fact that the effect of the second liming was conspicuously less than that of the first, as is obvious from chart 9.

If the effects of liming on the yields of wheat where the cowpeas were removed, as shown in chart 10, be compared with those where the cowpea crops were turned under, as shown in chart 11, it is evident that the effects of liming were most pronounced on

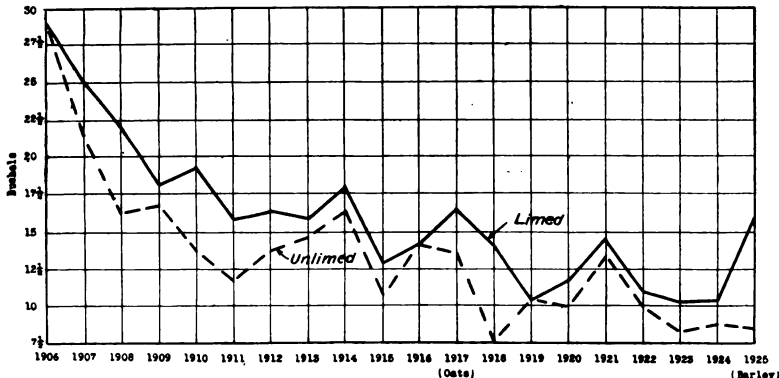


Chart 10—Yields of wheat from limed and unlimed sections of plots G4, G5, G8 and I4 (averaged)—all cowpea crops removed—Knoxville

Note the marked effect of liming throughout the period.

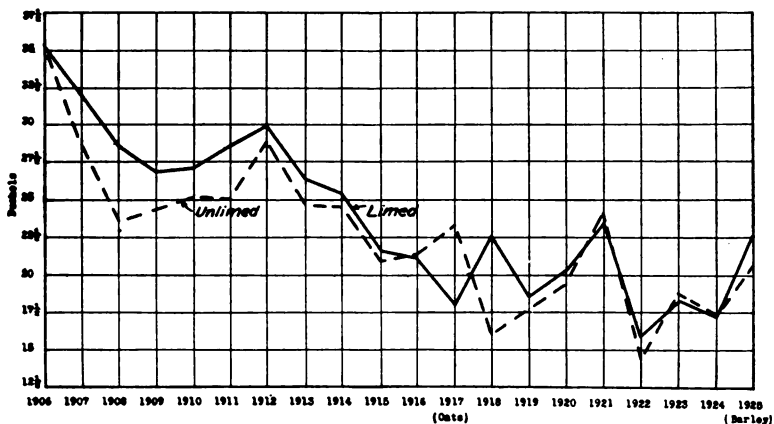


Chart 11—Yields of wheat from limed and unlimed sections of plots F4, F5, F8 and H4 (averaged)—all cowpea crops turned under—Knoxville

those plots where the crops were removed. Until 1914, however, the effects of the first liming are plainly evident on the plots where the cowpea crops were turned under and the second liming was followed by increased yields for each of the 3 years following, after which, or for the last 5 years, the limed and unlimed sections yielded practically alike.

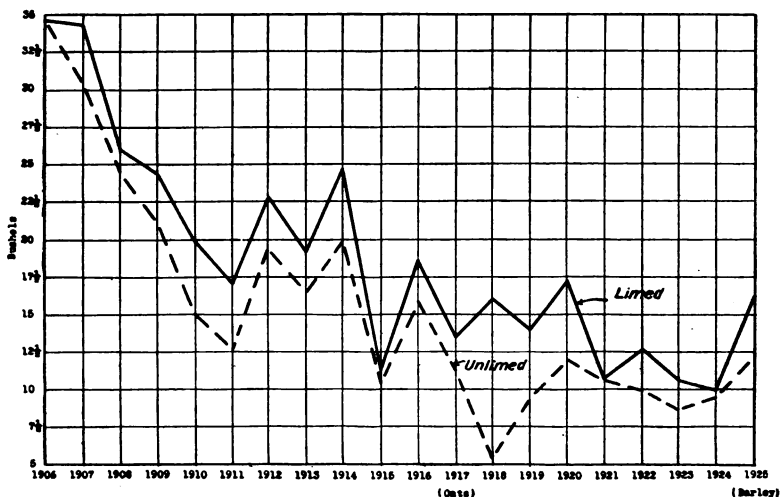


Chart 12—Yields of wheat from plot H5—wheat after summer fallow—Knoxville

INFLUENCE OF THE COWPEA CROPS ON THE YIELDS OF WHEAT

Chart 11 shows that the yields of wheat were not maintained, even where the cowpea crops were turned under, but continued to decline slowly, at least for the first 14 years. The yields on the corresponding plots where the cowpea crops were removed fell very rapidly during the first 6 years, as indicated in chart 10. A less marked downward tendency continued to the close of the period, with an average yield for the 20 years of 8 bushels per acre less than where the cowpea crops were turned under.

There was available only one no-cowpea plot, H5, for comparison with the cowpea plots as to the effects of the cowpeas on the wheat yields. The uniformity of the entire area used in the experiments was considered to be excellent, and plot H5 was as well located as possible in this respect, so that it may be considered as a dependable control. Since this plot received annual applications of phosphate and potash, the crop yields should be compared with those similarly treated, such as F5 and F8, where the cowpea crops were turned under, and G5 and G8, where the cowpea crops were removed. Chart 3 admits of this comparison when the yields from the limed and unlimed sections are averaged together. The yields from both the limed and unlimed sections of plot H5 are shown in chart 12. It is evident that the yields of this plot fell off rapidly, resembling closely those from G5 and G8, where the cowpea crops were removed. Plot H5 maintained, however, a higher yield for the first 4 years than F5 and F8. On the other hand, the yields for the last 10 years of the 20-year period averaged .7 bushel per acre less than those from G5 and G8, and 10.1 bushels less than those from F5 and F8.

RECOVERY OF NITROGEN FROM THE COWPEAS TURNED UNDER

The average annual yield of wheat from plots F5 and F8, where the cowpeas were turned under, was 25.5 bushels of grain and 2,980 pounds of straw per acre. The average yield from the similarly fertilized plots G5 and G8, from which the cowpea crops were removed, was 15.8 bushels of grain and 1,640 pounds of straw. Utilizing these data, which appear to be the best for this purpose that the experiments afford, and applying the same figures for the nitrogen content of the crops as used in the calculations relating to manure, we find the nitrogen recovery of the cowpea crops turned under to be 32.5 per cent when measured by the wheat crop only. If, as in the calculations relating to the nitrogen recovery from manure, the increased yield of cowpeas be taken into con-

sideration, the per cent of nitrogen recovery is increased to 42.5 per cent.

SOIL STUDIES

NITROGEN

At the outset of the experiments, and before any crop was grown, soil samples were carefully taken from each plot to a depth of 8 inches. Periodically thereafter samples were taken with care from both the limed and unlimed halves. These samples were analyzed by the Gunning method for total nitrogen. Precautions were taken to make these determinations in as nearly uniform a manner as possible; standard acid of constant strength being used with 10-gram charges of soil, and blanks run on reagents. In the course of this and similar work, however, the fact was established that it is very difficult, if not impossible, to obtain in practice absolutely comparable results between periodical soil samples. The samples, for various reasons, may not be representative of the conditions. A constant analytical error affecting the results to a few thousandths of a per cent may easily run throughout the series of determinations for any year; but this was guarded against as far as possible. For the reasons mentioned the comparative results between the plots cropped differently and between the limed and unlimed areas are more dependable than the differences appearing from one period to another. The writer believes, however, that the averages from several plots, as made use of in the discussions, give a fair index to the actual changes which took place in the content of total soil nitrogen.

Table 17 gives in detail the percentages of total nitrogen found in both the limed and unlimed sections of each plot, at intervals of 2 to 3 years throughout the period. Table 8 summarizes the data of table 17 with regard to the disposition of the cowpea crops; that is, annual averages are given both for the 13 plots where the cowpea crops were turned under and for the 4 unmanured plots where the cowpea crops were removed. Chart 13 presents graphically the data of table 8.

EFFECTS OF GREEN MANURING

As shown in chart 13, there was a positive continued decline in the nitrogen content of the soil for the first 10 years. This was true not only where the cowpeas were removed but also where they were turned under, although the decline under the former condition was much more marked than under the latter. Since that time a state of equilibrium seems to have been maintained, with an almost constant difference of .012 per cent of nitrogen in favor of the plots where the cowpea crops were turned under. At the

TABLE 8—*Effects of liming on the nitrogen content of the soil with regard to the disposal of the cowpea crops—summary of table 17.*

| Plots averaged | Disposition of cowpea crops | Year | Nitrogen content of soil | | |
|---|-----------------------------|------|--------------------------|------------------|----------------|
| | | | Limed | Unlimed | Average |
| G4, 5, 8, and I4 | Removed | 1905 | Per cent (.1238) | Per cent (.1238) | Per cent .1238 |
| | " | 1907 | .1189 | .1192 | .1165 |
| | " | 1910 | .1113 | .1157 | .1135 |
| | " | 1913 | .1075 | .1106 | .1090 |
| | " | 1915 | .1040 | .1043 | .1042 |
| | " | 1917 | .1045 | .1051 | .1048 |
| | " | 1919 | .1050 | .1070 | .1060 |
| | " | 1925 | .1017 | .1040 | .1029 |
| F4, 5 and 8
H4, 6 and 8
I5, 6 and 8
J4, 5, 6 and 8 | Turned under | 1905 | (.1266) | (.1266) | .1266 |
| | " | 1907 | .1204 | .1217 | .1210 |
| | " | 1910 | .1157 | .1196 | .1177 |
| | " | 1913 | .1192 | .1191 | .1191 |
| | " | 1915 | .1154 | .1150 | .1152 |
| | " | 1917 | .1167 | .1164 | .1166 |
| | " | 1919 | .1148 | .1147 | .1148 |
| | " | 1925 | .1169 | .1157 | .1163 |

outset the average content of soil nitrogen for the 13 plots where the cowpeas were turned under was .1266 per cent, and at the end of 10 years it was .1152 per cent, showing a loss of practically 9 per cent. In the case of the 4 plots where the cowpeas were removed for hay, the average per cent at the outset was .1236 and at the end of 10 years it was .1042 per cent, showing a loss in this case of 15.7 per cent. When calculated to pounds per acre for

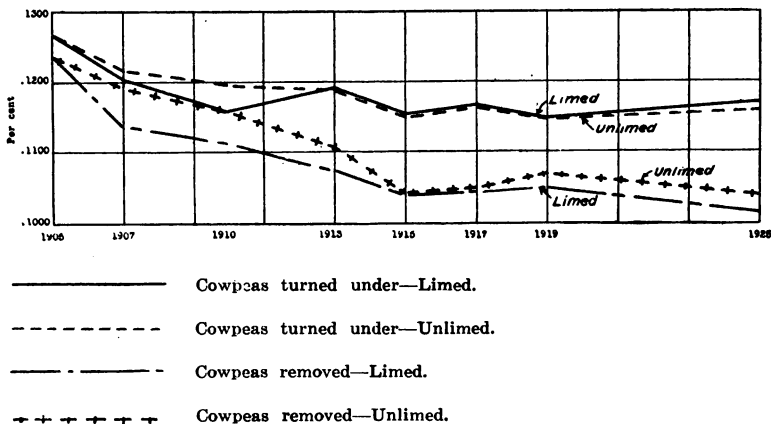


Chart 13—Changes in nitrogen content of soil—cowpea-wheat experiments—Knoxville

the depth sampled (8 inches), or 2,000,000 pounds of dry, fine soil, the loss of nitrogen for the first 10 years amounts to 228 pounds where the cowpeas were turned under and 388 pounds where they were removed.

EFFECTS OF LIMING

Some striking changes took place after the first liming, as indicated in chart 13. In the case of the 13 plots where the cowpeas were turned under, the limed sections showed a considerably lower content of nitrogen for a period of between 5 and 8 years. The maximum difference found was in 1910, when there was nearly .005 per cent, or approximately 100 pounds per acre, less nitrogen in the limed sections than in the unlimed. After 1913 there was no appreciable difference between them. In the case of the 4 plots from which the cowpeas were removed a similar reduction in nitrogen content followed liming, but with the difference that the marked reduction continued for a period of at least 8 years, after which the per cent continued to be slightly in favor of the unlimed sections.

The effects of the second liming are little in evidence. In the case of the 4 plots where the cowpea crops were removed there appears to be some loss of nitrogen attributable to the reliming, the difference between the nitrogen contents of the soil of the limed and unlimed sections being more favorable to the latter, both in 1919 and in 1925, than in either 1915 or 1917. Under both conditions the per cent of nitrogen tends downward, being less in 1925 than at any other time since 1913. In the case of the 13 plots where the cowpea crops were turned under, there is no sign of depression attributable to liming. On the contrary there has been a tendency since 1913 toward higher percentages under the limed condition. It is of interest to note that under both conditions the nitrogen content of the soil has been practically maintained for the past 10 years.

CORRELATION BETWEEN NITROGEN DATA AND CROP PRODUCTION

There is a striking correlation between the more rapid loss of soil nitrogen from the limed sections following the first liming and the increased crop production of the same sections during the same period. Under normal conditions, loss of soil nitrogen may be used as a measure of its conversion into forms available for plant use. The soil results therefore confirm the crop data in demonstrating that in these experiments the crop yields were increased by liming largely, if not almost entirely, because of an increased supply of available soil nitrogen.

LIMINGS NOT INJURIOUS

Attention is also called to the important fact that the limings do not appear to have caused any special waste of soil nitrogen, but rather to have accelerated for a time losses of nearly equal magnitude which took place at a more nearly uniform rate where no liming was done.

HUMUS

CHANGES IN TOTAL HUMUS CONTENT

The determination of the organic carbon of a soil can be made accurately, but there is no accurate method of determining the actual amount of "humus". When, however, the carbon content is multiplied by a suitable factor, a close approximation of the amount of organic matter is obtained. Table 9 gives the humus content, determined in this way at the beginning of the experiments in 1905 and at the end of 20 years, with regard to the effects of various treatments. The table summarizes the results obtained from the individual soil analyses for each of 19 plots.

EFFECTS OF GREEN MANURING

The results given in table 9 show less humus by .11 per cent at the end of the 20-year period where the cowpea crops were turned under annually. When calculated to the 8-inch depth of

TABLE 9—Changes in the total humus content ($C \times 1.724$) of the soil under various conditions at the end of 20 years—Knoxville experiments (m. f. basis).

| Plots averaged | Disposition of cowpea crops | Humus content in 1905 | Humus content in 1925 | | | | | |
|---|-----------------------------|-----------------------|-----------------------|----------------------------|----------------|----------------------------|------------------------------|----------------------------|
| | | | Limed | | Unlimed | | Average of limed and unlimed | |
| | | | | Gain (+)
or
loss (—) | | Gain (+)
or
loss (—) | | Gain (+)
or
loss (—) |
| G4, 5, 8, I4 | Removed | P. ct.
2.34 | P. ct.
2.06 | —11.97 | P. ct.
2.14 | —8.55 | P. ct.
2.10 | —10.26 |
| F4, 5, 8
H4, 6, 8
I5, 6, 8
J4, 5, 6, 8 | Turned under | 2.45 | 2.35 | —4.08 | 2.33 | —4.90 | 2.34 | —4.49 |
| F6, G6 | Removed
(Manured) | 2.59 | 2.76 | +6.56 | 2.64 | +1.93 | 2.70 | +4.25 |

sampling, this loss amounts to 2,200 pounds per acre. Where the cowpea crops were removed (plots G4, G5, G8, and I4) the loss was appreciably greater, amounting to .24 per cent, or 4,800 pounds per acre. Two thousand six hundred pounds therefore approximates the amount of humus left from turning under 20 crops of cowpea

hay, averaging 1.1 tons per acre, or a total of 22 tons, furnishing nearly 20 tons of actual dry matter. This crop is quickly decomposed in the soil, and although it may supply a current of fresh humus, it evidently makes no great contribution to the permanent humus supply.

EFFECTS OF FARMYARD MANURE

The manure was rich in both organic matter and nitrogen, and supplied, according to calculation, about one-third more organic matter than the incorporated cowpea crops. The analyses indicate that the manure plots are the only ones on which there was an increase in humus; the soil content being 2.59 per cent in 1905 and 2.70 per cent in 1925. The calculated gain in humus per acre for the depth of plowing was therefore 2,200 pounds.

EFFECTS OF LIMING

The effects of liming on the humus content of the soil at the end of the 20-year period are little in evidence. Where the cowpea crops were removed, however, there was a greater loss under the limed than the unlimed condition, the difference being .08 per cent, or 1,600 pounds per acre. On the other hand, where the cowpea crops were turned under the limed sections show a slightly higher content than the unlimed. The limed sections of the manure plots have an appreciably higher humus content than the unlimed, but this result must be taken with reservations because there were only two plots concerned in the average and they were adjacent. It is possible that the limed section had originally a somewhat higher content than the unlimed. There are also unavoidable errors in sampling which could easily be accentuated where manure applications have been made.

ACTIVE HUMUS

Table 10 gives the percentages of the more active, or colloidal, humus in the soil samples, which were taken every 2 or 3 years for the first 10 years of the experiments. As in table 9, the results are averages of separate determinations for each plot. These determinations are made by extracting the humus with dilute ammonia after leaching with dilute hydrochloric acid—a method once commonly used, but nearly abandoned of late years, chiefly because the method gives less accurate results than that for total carbon. In these experiments there is, however, much similarity in the trend of the results by the two methods. At the end of the 10-year period the soil from the plots where the cowpeas were removed has lost appreciably the most colloidal humus, and the limed sections have suffered a somewhat greater loss than the un-

TABLE 10—*Colloidal humus content of soils under various conditions as determined periodically for the first 10 years of the Knoxville experiments (m. f. basis).*

| Plots averaged | Disposition of cowpea crops | 1905 | 1907 | | 1910 | | 1913 | | 1915 | |
|--|-----------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| | | | Limed | Un-limed | Limed | Un-limed | Limed | Un-limed | Limed | Un-limed |
| G4, 5, 8, I4 | Removed | P. ct. 1.26 | P. ct. 1.21 | P. ct. 1.29 | P. ct. 1.22 | P. ct. 1.29 | P. ct. 1.20 | P. ct. 1.30 | P. ct. 1.14 | P. ct. 1.20 |
| F4, 5, 8
H4, 6, 8
I5, 6, 8
J4, 5, 6, 8, | Turned under | 1.29 | 1.26 | 1.29 | 1.30 | 1.35 | 1.28 | 1.31 | 1.23 | 1.23 |
| F6, G6 | Removed (Manured) | 1.39 | 1.43 | 1.44 | 1.40 | 1.52 | — | 1.58 | 1.43 | 1.45 |

limed. The loss is less where the cowpea crops were turned under, but the content is the same for the limed as the unlimed. The manure plots show a gain, but the difference between the limed and unlimed sections is not positive. In fact, they are closer than duplicate determinations often are from the same soil sample.

Perhaps the most interesting point brought out in this series is the more immediate effect of liming on the humus matter, the effect being similar to that on the soil nitrogen. That is, liming lowered the content of colloidal humus under all conditions during the earlier years. This effect disappears, however, by the tenth year in the case of both the manure plots and the plots where the cowpea crops were turned under. Where the cowpeas were removed the effect is more persistent, being plainly in evidence at the end of the period, although it appears to be of little practical consequence.

RESULTS OBTAINED AT THE JACKSON STATION

Experiments similar to those at Knoxville were conducted for 16 years, 1909-1925, at the West Tennessee Station, at Jackson, with the production of 17 crops of cowpeas and 16 of wheat. The climate of Jackson is better suited to this kind of rotation than the climate of Knoxville, the summer season at the former place being somewhat longer and warmer, and hence more favorable to the cowpea crop and to a late seeding of wheat.

DATES OF PLANTING AND HARVESTING

The dates of planting wheat varied from October 2 to November 12, with October 16 as the average. The dates of harvest varied from June 6 to 19, with June 11 as the average.

The dates of planting the cowpeas varied from June 9 to July 16, with June 21 as the average. The hay crops were cut from August 21 to October 18, with September 9 as the average.

TABLE 11—*Chemical analyses of soils.*
(10-hour digestion with hydrochloric acid, Sp. Gr. 1.115)

| Constituent | Knoxville soil | Jackson soil |
|------------------------------|----------------|--------------|
| | Per cent | Per cent |
| Insoluble residue | 82.49 | 91.45 |
| Potash (K_2O) | 0.34 | 0.20 |
| Lime (CaO) | 0.13 | 0.15 |
| Magnesia (MgO) | 0.25 | 0.32 |
| Manganese oxide (MnO) | 0.24 | 0.17 |
| Ferric oxide (Fe_2O_3) | 3.27 | 1.43 |
| Alumina (Al_2O_3) | 6.61 | 3.41 |
| Phosphoric acid (P_2O_5) | 0.14 | 0.057 |
| Sulphuric acid (SO_3) | 0.04 | 0.04 |
| Volatile matter | 5.55 | 2.52 |
| Humus | 1.36 | 0.68 |
| Total nitrogen | 0.128 | 0.064 |
| Acidity by Veitch method | 0.07 | 0.02 |
| Colloids | 21.50 | 9.40 |

SOIL AND PLOTS

The soil was a grayish-brown silt loam of good structure, underlaid by a somewhat heavier reddish-yellow subsoil to a depth of about 2 feet, below which was a stratum of sand of unknown depth. The land was uniform and nearly level throughout.

For comparative purposes the chemical analyses of both the Knoxville and Jackson soils are given in table 11 and mechanical analyses in table 12. According to the chemical analyses the Jack-

TABLE 12—*Mechanical analyses of soils.*
(By method of Bureau of Soils)

| Class | Size of particles | Knoxville soil | Jackson soil |
|----------------|-------------------|----------------|--------------|
| | mm | Per cent | Per cent |
| Gravel | 2. - .1. | 1.14 | 0.17 |
| Coarse sand | 1. - .5 | 2.37 | 1.35 |
| Medium sand | .5 - .25 | 3.32 | 2.77 |
| Fine sand | .25 - .1 | 9.15 | 4.27 |
| Very fine sand | .1 - .05 | 17.68 | 5.77 |
| Silt | .05 - .005 | 47.85 | 76.00 |
| Clay | .005-0 | 19.63 | 9.68 |

son soil has slightly better supplies of both lime and magnesia than the Knoxville soil, but the content of potash, phosphoric acid, nitrogen, and humus is less for each by nearly one-half. The important differences, as shown in the mechanical analyses, are the comparatively high content of silt in the Jackson soil and of both clay and colloids in the Knoxville soil. The latter soil is "heavier"

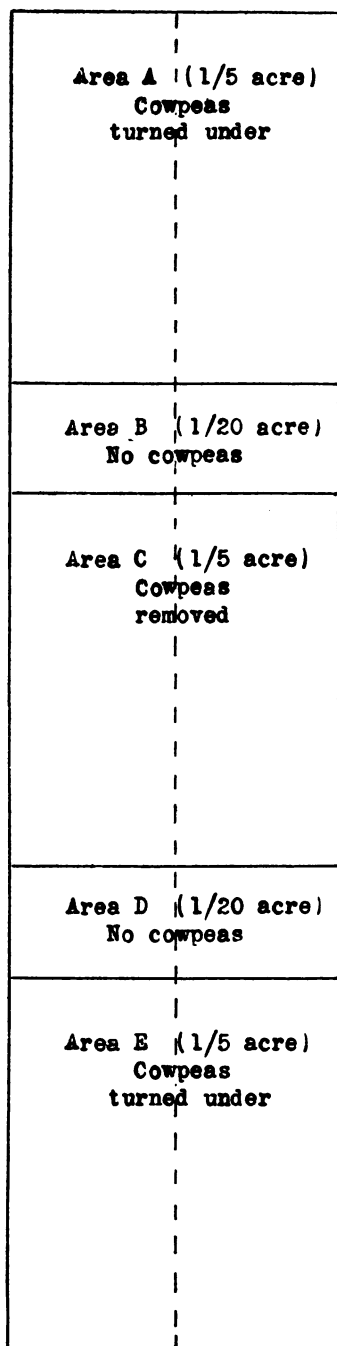


Diagram 2—Experimental range—Jackson

and more granular than the former, and more subject to heaving in the winter.

The Jackson soil, however, proved to be well supplied with available phosphate and potash, so that no increased yield from their application in the case of either cowpeas or wheat was at any time evident in the course of the 16 years. For the present purposes, therefore, the areas, originally laid out in 1/40-acre plots to test the special plant-food requirements, have been grouped together. But it should be stated that the fertilizer treatments were the same where the cowpea crops were turned under as where removed, and that the majority of the plots received both phosphate and potash.

One-half of the range was limed lengthwise in 1909, prior to the first cowpea crop. The second liming was made in 1919, prior to the cowpea crop of that year. One-half of the plots under each of the major conditions was limed with burnt lime at the rate of 1 ton per acre and the others with ground limestone at the rate of 2 tons per acre; but since no noticeable difference in the effectiveness of the two materials appeared in the crop yields no further reference to the matter will be made.

Diagram 2 shows the divisions of the experimental range.

DISCUSSION OF THE DATA

THE EFFECTS OF LIMING ON THE YIELD OF COWPEAS

The annual crop yields are summarized in table 13 and given for the individual areas in table 18. The response to liming was especially marked the first 13 years, 1909-1921; the average annual increase for that period being 860 pounds of hay per acre, or 44.3 per cent. During the last 4 years, 1922-1925, the response to liming was much reduced, the average yearly increase being 320 pounds of hay, or only 17.8 per cent.

Charts 14 and 15 present graphically the annual yields obtained both with and without liming—chart 14 where the crops were turned under and chart 15 where they were removed. The trend of the curves shown in the two charts is similar, but the yields were at a lower level where the crops were removed. The difference between the yields on the limed and unlimed sections is nearly the same in the two cases. For the 17 years the average annual production where the crops were turned under was 1.46 tons of hay per acre on the limed section and 1.08 tons on the unlimed. Where the hay was removed the limed section averaged 1.27 tons and the unlimed .94 ton. A tendency to decreased yields is seen where the crops were removed, but little or no tendency in this direction where the crops were turned under.

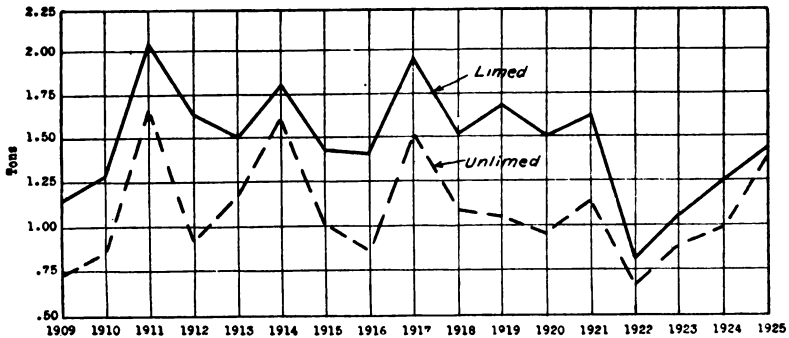


Chart 14—Yields of cowpea hay from limed and unlimed sections of areas A and E (averaged)—cowpea crops turned under each year—Jackson

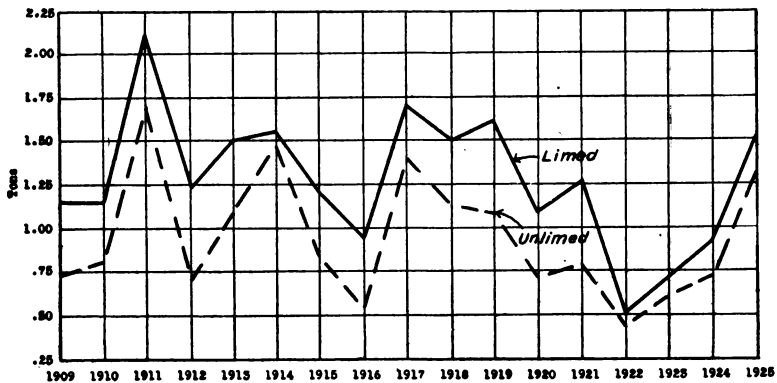


Chart 15—Yields of cowpea hay from limed and unlimed sections of area C—cowpea crops removed annually—Jackson

THE EFFECTS OF LIMING ON THE YIELD OF WHEAT

Table 13 summarizes the yields of wheat obtained both with and without liming. Liming resulted in a markedly superior yield of both grain and straw throughout the period. On the average for the 16 years the increase per acre from liming was 3.5 bushels of grain and 600 pounds of straw where the cowpea crops were removed, 5.8 bushels of grain and 1,000 pounds of straw where the cowpea crops were turned under, and 3.1 bushels of grain and 420 pounds of straw where no cowpeas were grown.

A graphic comparison between the yields from the limed and unlimed sections of the entire 25 plots of the range is given in

chart 16. In 14 of the 16 years the limed section materially out-yielded the unlimed. Only in 1916 and 1919 did the sections yield

TABLE 13—Average annual yields per acre of (1) cowpea hay and (2) wheat under the various experimental conditions, at Jackson Station, over 16-year period, 1909-1925.

| Disposition of cowpea crops | Year | Cowpea Hay | | | Wheat | | | | | |
|--|---------|------------|-----------|-------------------------------|----------|-----------|---------|-----------|------------------------------|-----------|
| | | Limed | Un-limed | Average of limed and un-limed | Limed | | Unlimed | | Average of limed and unlimed | |
| | | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| Area C
Cowpea hay removed each year (plots 10-16) | 1909-10 | Tons 1.15 | Tons 0.78 | Tons 0.94 | Bu. 13.7 | Tons 2.16 | Bu. 6.8 | Tons 1.03 | Bu. 10.3 | Tons 1.60 |
| | 1910-11 | 1.15 | 0.81 | 0.98 | 15.3 | 1.88 | 7.5 | 1.33 | 11.4 | 1.61 |
| | 1911-12 | 2.11 | 1.67 | 1.89 | 27.8 | 1.56 | 21.5 | 1.35 | 24.7 | 1.46 |
| | 1912-13 | 1.23 | 0.70 | 0.97 | 19.3 | 1.04 | 15.2 | 0.89 | 17.3 | 0.97 |
| | 1913-14 | 1.50 | 1.09 | 1.30 | 14.9 | 0.72 | 13.2 | 0.73 | 14.1 | 0.73 |
| | 1914-15 | 1.55 | 1.46 | 1.51 | 18.2 | 0.72 | 18.1 | 0.86 | 18.2 | 0.79 |
| | 1915-16 | 1.21 | 0.83 | 1.02 | 07.5 | 0.52 | 10.3 | 0.69 | 08.9 | 0.61 |
| | 1916-17 | 0.94 | 0.55 | 0.75 | 22.5 | 0.87 | 15.4 | 0.68 | 19.0 | 0.78 |
| | 1917-18 | 1.68 | 1.40 | 1.54 | 19.4 | 0.91 | 16.4 | 0.69 | 17.9 | 0.80 |
| | 1918-19 | 1.50 | 1.13 | 1.32 | 14.0 | 0.71 | 13.8 | 0.67 | 13.9 | 0.69 |
| | 1919-20 | 1.61 | 1.08 | 1.35 | 17.5 | 0.96 | 14.5 | 0.63 | 16.0 | 0.80 |
| | 1920-21 | 1.09 | 0.71 | 0.90 | 22.9 | 1.58 | 16.9 | 0.98 | 19.9 | 1.28 |
| | 1921-22 | 1.26 | 0.78 | 1.02 | 18.7 | 1.31 | 17.5 | 1.08 | 18.1 | 1.20 |
| | 1922-23 | 0.50 | 0.42 | 0.46 | 21.6 | 1.87 | 13.9 | 1.03 | 20.3 | 1.20 |
| | 1923-24 | 0.72 | 0.61 | 0.67 | 23.2 | 1.79 | 17.9 | 0.96 | 20.6 | 1.38 |
| | 1924-25 | 0.98 | 0.72 | 0.83 | 19.0 | 1.09 | 16.6 | 0.86 | 17.8 | 0.98 |
| | 1925 | 1.53 | 1.26 | 1.40 | | | | | | |
| | Average | 1.27 | 0.94 | 1.11 | 18.5 | 1.20 | 15.0 | 0.90 | 16.8 | 1.05 |
| Areas A and B
Cowpea hay turned under each year (plots 1-7 and 19-25) | 1909-10 | 1.15 | 0.73 | 0.94 | 12.4 | 1.86 | 7.1 | 1.07 | 9.8 | 1.47 |
| | 1910-11 | 1.28 | 0.85 | 1.07 | 17.2 | 2.25 | 9.1 | 1.41 | 13.2 | 1.88 |
| | 1911-12 | 2.04 | 1.67 | 1.86 | 29.0 | 1.70 | 22.5 | 1.40 | 25.8 | 1.65 |
| | 1912-13 | 1.63 | 0.90 | 1.27 | 23.0 | 1.80 | 19.7 | 1.24 | 23.9 | 1.52 |
| | 1913-14 | 1.50 | 1.16 | 1.33 | 25.0 | 1.42 | 17.8 | 1.05 | 21.4 | 1.24 |
| | 1914-15 | 1.80 | 1.60 | 1.70 | 31.7 | 1.62 | 25.8 | 1.23 | 28.5 | 1.45 |
| | 1915-16 | 1.42 | 1.00 | 1.21 | 13.1 | 1.13 | 10.2 | 0.88 | 11.7 | 0.98 |
| | 1916-17 | 1.40 | 0.85 | 1.13 | 31.4 | 1.60 | 24.3 | 1.12 | 27.9 | 1.36 |
| | 1917-18 | 1.95 | 1.52 | 1.74 | 30.6 | 1.60 | 26.2 | 1.23 | 28.4 | 1.42 |
| | 1918-19 | 1.51 | 1.09 | 1.30 | 20.5 | 1.31 | 19.8 | 1.17 | 20.2 | 1.24 |
| | 1919-20 | 1.67 | 1.03 | 1.35 | 25.8 | 1.78 | 18.7 | 1.06 | 22.3 | 1.42 |
| | 1920-21 | 1.50 | 0.95 | 1.23 | 29.6 | 2.48 | 20.4 | 1.53 | 25.0 | 2.03 |
| | 1921-22 | 1.61 | 1.13 | 1.37 | 26.6 | 2.17 | 22.3 | 1.61 | 24.5 | 1.39 |
| | 1922-23 | 0.80 | 0.67 | 0.74 | 25.2 | 1.95 | 19.8 | 1.38 | 22.5 | 1.67 |
| | 1923-24 | 1.05 | 0.88 | 0.97 | 31.2 | 1.96 | 24.1 | 1.37 | 27.7 | 1.67 |
| | 1924-25 | 1.25 | 0.99 | 1.12 | 26.3 | 1.84 | 23.3 | 1.56 | 24.8 | 1.70 |
| | 1925 | 1.43 | 1.36 | 1.40 | | | | | | |
| | Average | 1.46 | 1.08 | 1.28 | 25.2 | 1.77 | 19.4 | 1.27 | 22.3 | 1.52 |
| Areas B and D
No cowpeas grown (plots 8, 9 and 17, 18) | 1909-10 | | | | 14.2 | 2.26 | 9.6 | 1.53 | 11.9 | 1.90 |
| | 1910-11 | | | | 21.1 | 2.46 | 11.5 | 1.37 | 16.3 | 2.17 |
| | 1911-12 | | | | 21.3 | 1.16 | 21.1 | 1.16 | 21.2 | 1.16 |
| | 1912-13 | | | | 22.6 | 1.61 | 21.4 | 1.43 | 22.0 | 1.55 |
| | 1913-14 | | | | 15.7 | 0.89 | 15.4 | 1.00 | 15.6 | 0.95 |
| | 1914-15 | | | | 20.2 | 1.01 | 17.9 | 0.88 | 19.1 | 0.95 |
| | 1915-16 | | | | 07.8 | 0.65 | 08.0 | 0.69 | 07.9 | 0.67 |
| | 1916-17 | | | | 19.4 | 0.31 | 12.3 | 0.59 | 15.9 | 0.70 |
| | 1917-18 | | | | 19.2 | 1.03 | 18.5 | 0.97 | 18.9 | 1.00 |
| | 1918-19 | | | | 10.7 | 0.75 | 10.6 | 0.74 | 10.7 | 0.75 |
| | 1919-20 | | | | 14.4 | 0.85 | 11.1 | 0.72 | 12.8 | 0.79 |
| | 1920-21 | | | | 17.4 | 1.13 | 9.9 | 0.96 | 13.7 | 1.05 |
| | 1921-22 | | | | 16.5 | 1.48 | 14.3 | 1.03 | 15.4 | 1.26 |
| | 1922-23 | | | | 17.8 | 1.34 | 13.3 | 1.06 | 15.6 | 1.20 |
| | 1923-24 | | | | 21.6 | 1.51 | 15.6 | 1.26 | 18.6 | 1.39 |
| | 1924-25 | | | | 12.5 | 1.26 | 12.9 | 0.84 | 12.7 | 1.05 |
| | Average | | | | 17.0 | 1.26 | 13.9 | 1.05 | 15.5 | 1.15 |

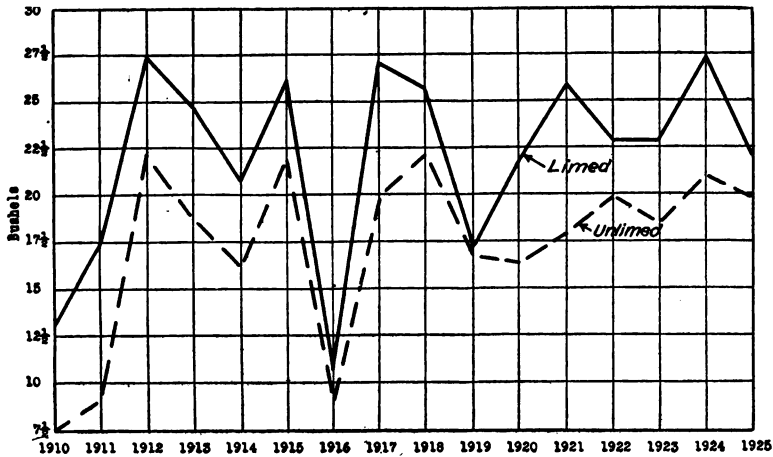


Chart 16—Yields of wheat with and without liming—Jackson

practically alike. The 1916 crop was produced in the most unfavorable of all the seasons. The 1919 crop was the last prior to the reliming of that year. There are indications that the reliming increased the difference between the yields of the two sections, and no positive evidence of declining effectiveness of the liming has appeared, so far as the wheat crop is concerned.

THE INFLUENCE OF THE COWPEA CROP ON THE YIELD OF WHEAT

Table 13 may be referred to again for the influence of the cowpea crop on wheat production under three conditions: (1) Cowpeas removed, (2) cowpeas turned under, and (3) summer fallow. A graphic comparison of the yields under the various conditions is given in chart 17.

On the average for the 16 years the yields of wheat were 1.3 bushels per acre greater and the straw production 200 pounds less on area C, where the cowpea crops were removed as hay, than on areas B and D, where no cowpeas were grown. If, however, the yields for the first 8 years be compared with those for the last 8, much light is thrown on what has taken place, for during the first 8 years the no-cowpea plots outyielded area C by an average of .7 bushel of grain and 420 pounds of straw to the acre, but in the last 8 years area C outyielded the no-cowpea plots by an average of 3.3 bushels of grain, with a straw production only 40 pounds less than that of the no-cowpea plots. The average annual acre

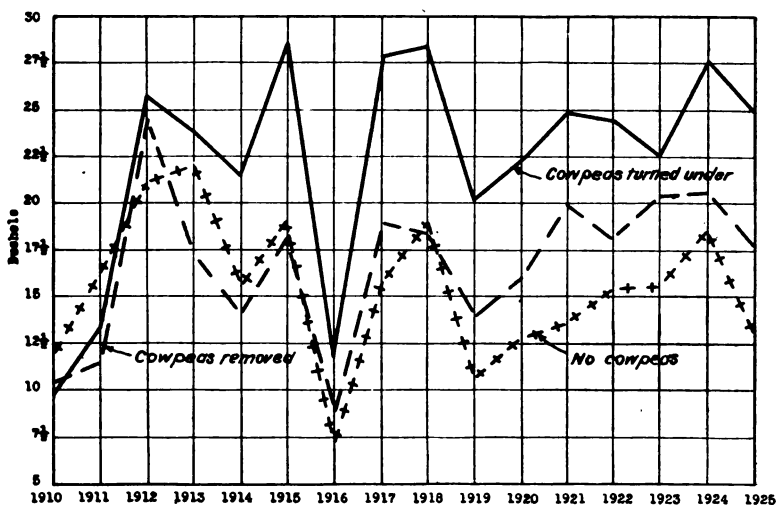


Chart 17—Yields of wheat under various conditions—Jackson

yield of wheat on area C was 16.8 bushels of grain and 1.05 tons of straw, or within the range of profitable production.

On areas A and E, where the cowpea crops were turned under, the yields of wheat were especially good and the tendency is upward. For the entire period they produced an annual average of 6.8 bushels of grain and 740 pounds of straw per acre more than where no cowpeas were grown. The average yield per acre on areas A and E during the first 8 years was 20.3 bushels of grain and 1.43 tons of straw. For the last 8 years the averages were 24.4 bushels of grain and 1.63 tons of straw.

RELIMING AND THE LAW OF DIMINISHING RETURNS

PRELIMINARY CONSIDERATIONS

The following brief preliminary considerations of some well-established fundamentals relating to liming may be of assistance in the interpretation of the experimental data and in the establishing of principles of wide practical application:

Liming has been found to promote crop production under a number of soil conditions, prominent among which are the following:

1. Acid, or "sour", soil.
2. Soil containing injurious metallic salts—a usual result of soil acidity.

3. Soil deficient in available calcium for plant-food purposes, especially in the case of leguminous crops with high lime requirements.

4. Soil in which liming induces a material speeding up of nitrification and other oxidation processes.

Although one or other of these conditions is often in the ascendency, their inter-relation and the probability of two or more being concerned should be kept in mind.

It is well known that crops differ to a marked degree in their response to liming. Cotton, for example, may thrive without liming, while alfalfa may fail. Rhode Island Experiment Station Bulletin No. 46, on "Lime and Liming", by Director H. J. Wheeler, gives the relative responses of numerous crops to liming, as found in field trials. In these trials all crops were well fertilized; nitrate of soda "in generous quantities" being included in the applications. Of the 5 crops used in the cowpea-wheat experiments at Knoxville, 4—barley, wheat, oats, and soybeans—are included by Wheeler among those benefited by liming. Cowpeas he found to be slightly injured. The crops benefited were not found to respond equally to liming. With 1.00 to indicate no response, he gave the standing of the 5 crops as follows:

| | |
|----------------|------|
| Barley | 2.06 |
| Wheat | 1.40 |
| Oats | 1.09 |
| Soybeans | 1.06 |
| Cowpeas | 0.94 |

As compared with these 5, many other crops were found to be far more largely benefited by liming. Lettuce, for example, was rated at 10.00, and table beets at 5.35. On the other hand, a number of crops, including millet and pumpkins, are mentioned, along with the cowpeas, as being injured by liming.

The low placement of wheat, oats, soybeans, and especially cowpeas, as regards responsiveness to liming is a further confirmation of the proof previously given that an increased supply of available nitrogen offers, in many respects, a satisfactory explanation of the superior yields obtained under liming in the Knoxville experiments. The Knoxville data, on the other hand, do not appear to harmonize with any of the other 3 major conditions mentioned. Assuming the correctness of the conclusion reached, one may well ask what is the outcome of the continued liming of such a soil, so far, of course, as the crops in question are concerned.

THE KNOXVILLE EVIDENCE

In the answer to this question with regard to the Knoxville evidence, two important conditions may well be considered. One is, where either no cowpeas were grown, or, if grown, the crops were removed without return of manure; and the other is, where the cowpea crops were turned under annually and thus to an appreciable extent replenished the soil supply of both nitrogen and organic matter.

In the former case the soil analyses show a continued drain on the original supply of soil nitrogen—a condition which could hardly result in other than a decreasing effectiveness of liming. As a matter of fact, the first liming was uniformly effective in the case of the cowpea crop for the succeeding 9 years, but the second liming was evidently less effective; material increases in yield appearing in only 4 of the next 7 years. In the case of the wheat crops the first liming resulted in materially increased yields for 10 of the first 11 years following, but after the second liming, although the yields were favorable to the limed areas, the differences between the limed and unlimed areas were too small to be of special moment for at least 3 of the 8 years. In short, the effectiveness of reliming, with little, if any, renewal of the soil supply of nitrogen, became so reduced for both crops that the profitability of a third liming is very doubtful.

Where the cowpea crops were turned under there might be the expectation of a longer-continued effectiveness of lime because of the annual incorporation of organic matter. But such was not the outcome. Not only was there a comparatively small increase in the yield of cowpea hay from the first liming, but the second liming produced practically none. Although the first liming resulted in consistently increased yields of wheat for at least 7 years, the second liming was materially in evidence for only 1 year. In fact, for the last 5 years the differences between the crops produced on the limed and unlimed sections were not only very small but were favorable first to one section and then to the other. Apparently the lime content of the plants turned under was sufficient to supply that needed in their active nitrification.

THE JACKSON EVIDENCE

The soil at Jackson was initially much poorer in nitrogen than that at Knoxville, but the effect of liming has been considerably more pronounced for both the cowpea and the wheat crops. It may be, therefore, that an increased supply of available nitrogen was not the only prominent factor in the case. There is strong evidence, however, that the effectiveness of liming is diminishing.

For, although reliming was done only 5 years previous to the last cowpea crop, the differences in yield of cowpea hay between the limed and unlimed sections have been greatly reduced, and are, in fact, relatively small for the last 4 years.

Thus far no such decrease has appeared in the case of the wheat crop. This is not surprising, because at Knoxville the cowpea crop was the first to show no response; superior yields of wheat on the limed sections continuing for several years longer. In this connection it may be recalled that the data relating to wheat at Jackson are of 4 years' shorter duration than those at Knoxville.

The superior wheat crops at Jackson on the limed sections, as compared with the unlimed, can be attributed in part to the much larger cowpea crops, the after-effects of which would be expected to last for more than a single season.

Mention should be made of the fact that there could hardly have been any deficiency of sulphur in either the Knoxville or the Jackson soil. At each place from 50 to 60 pounds of sulphur per acre are yearly brought down by the rainfall. Had the case been otherwise the sulphur factor might have been of importance, because, as found by this Station, sulfonation is accelerated in a soil by liming much as is nitrification.

CONCLUSION AND COROLLARIES FROM THE COWPEA-WHEAT EXPERIMENTS

This review of the two series of experiments indicates a very important conclusion; namely, that the effects of liming on the yield of both cowpeas and wheat followed the law of diminishing returns. That is, the first liming acted as a soil stimulant, with marked increases in yield, which continued for a series of years; reliming was followed by a similar reaction, but of decreased intensity; and the unprofitableness of a third liming was indicated.

The following corollaries appear to be justified by the evidence presented, and are in harmony with miscellaneous data secured at various points in the State:

1. For soils rich in nitrogen, liming is not apt to increase the yields of either cowpeas or soybeans. In further support of this statement mention may be made of the fact that soybeans are among the few crops found to do well without liming on the dark-colored, "sour", "natural meadows" of the Cumberland Plateau. This soil is very rich in nitrogen and humus, but exceptionally poor in lime and other mineral elements of plant food.

¹MacIntire, W. H., Shaw, W. M., and Young, J. B. Influence of calcic and magnesian treatments upon sulphate leachings from soil alone and with additions of ferrous sulphate, pyrite and sulphur. *Soil Sci.* 16:3. Sept. 1923.

2. Lack of material response to liming by these cereals and legumes may be expected on soils with a very low content of nitrogen; the increase in available nitrogen being too small to be of consequence.

3. The Knoxville evidence indicates that a natural soil, even where all crops were removed, may be fairly well supplied with nitrogen, much as were the limed sections at the end of the 20-year period, but in such forms or under such conditions that liming results in little increase in the amount available to a growing crop.

APPLICATION OF THE LIMING DATA TO OTHER SOILS IN THE STATE

Tennessee soils vary appreciably in physical character and in plant-food supply, according to the geological formations from which they were derived. There are, however, certain general characteristics common to all, due largely to the fact that the soils were formed under similar climatic conditions. Among the general characteristics may be mentioned the rather low content of both lime and nitrogen and the preponderance of loam and silt-loam soils similar to those used in the experiments. The Experiment Station has made trial of liming on numerous types of soil scattered over the State, and the favorable response of such crops as corn, wheat, oats, soybeans, and cowpeas is general. There are, therefore, strong indications that an increase in the supply of available nitrogen is the most prominent cause of the results obtained in all parts of the State.

At this point a word of caution may be necessary in order to prevent possible misunderstanding relative to the desirability of liming. Even for the crops studied, no good reason is apparent why liming should not be practiced as long as the returns will justify the investment. With regard to such important soil-improving crops as red clover, sweet clover, and alfalfa, liming is a necessity to their profitable production over large areas in the State, and the law of diminishing returns does not appear to apply to them except as a minor factor. In support of this statement attention is called to the marked difference between the response to liming of various clovers and of cowpeas, soybeans, or wheat, as shown in the following data obtained at the Knoxville Station under conditions which were practically identical so far as soil, manurial treatments, and period of time are concerned, as those in the cowpea-wheat rotation:

EXPERIMENTS IN A 5-YEAR ROTATION WITH CLOVER AND GRASS

Experiments were begun in 1905 in a 5-year rotation of corn, soybeans, wheat, and clover and grass, on land adjacent to the cowpea-wheat plots. Seedings were made of crimson clover as a cover crop after corn, but only two harvestable crops were obtained. These were turned under, but all other crops of the rotation were removed. It should be noted that the clover and grass crop stood for 2 years after each seeding, and that the first year's crop was chiefly clover and the second year's chiefly grass. A total of 15 plots of 1/40-acre each were used under various manurial treatments, including liming—one-half of every plot being limed at the same time and rate in 1905 as the cowpea-wheat plots. The second liming was not done until 1919, because the 5-year-rotation plots were in sod at the time of the reliming of the cowpea-wheat plots in 1917.

For the present purpose the record of crop yields will be limited to the averages obtained from 5 plots lying nearest the cowpea-wheat plots, from which they were separated by a 12-ft. driveway.

These 5 plots, in the course of the 20 years, 1905-1925, received nearly the same manurial treatments as the manure plots, F6 and G6, of the cowpea-wheat experiments, except that the manure was not applied annually, but only for the corn and wheat crops—each receiving 9¼ tons of manure per acre. This amounts to an average annual application of 3.7 tons. Table 14 gives all the crop yields obtained under both limed and unlimed conditions. One other crop of wheat was harvested, and one of corn, but unfortunately the yields recorded were from the whole plots and not from the limed and unlimed portions separately. Chart 18 shows the yields of the various clover and grass crops, and may well be compared with chart 7, which shows the yields of the cowpea hay on plots F6 and G6.

DISCUSSION OF THE PLOT DATA

The yield of corn on the limed section was somewhat better than on the unlimed, but apparently the crop was limited in some seasons, as in 1919, by the rainfall rather than by the nitrogen supply. On the average the limed section produced nearly 4 bushels per acre more than the unlimed.

According to the writer's observations, soybeans respond to liming about the same as cowpeas. In this case 3 of the 4 soybean crops did as well on the unlimed as on the limed section. Only

TABLE 14—*Effects of liming on the yields per acre in a rotation of corn, soybeans, wheat, and clover and grass, in parallel experiments with those of the cowpea-wheat rotation at the Knoxville Station—all crops removed except two of crimson clover. Manuring and fertilizing similar to that given plots F6 and G6 in cowpea-wheat rotation.*

| Year | Limed | | Unlimed | | Year | Limed | Unlimed | |
|---------|-------|-----------------|---------|-----------------|------|------------------------|---------|------|
| | Grain | Straw or stover | Grain | Straw or stover | | | | |
| Wheat | | | | | | Clover and grass hay | | |
| | Bu. | Tons | Bu. | Tons | | Dominating constituent | Tons | Tons |
| 1911 | 26.9 | 1.61 | 25.0 | 1.62 | 1907 | Alsike clover | 2.10 | 0.62 |
| 1916 | 21.9 | 1.39 | 22.0 | 1.38 | 1908 | Grass | 3.18 | 2.13 |
| 1921 | 29.0 | 1.59 | 24.6 | 1.41 | 1910 | Crimson clover | 1.66 | 1.34 |
| | | | | | 1912 | Red clover | 1.66 | 1.17 |
| | | | | | 1913 | Grass | 0.62 | 0.49 |
| | | | | | 1915 | Crimson clover | 0.65 | 0.52 |
| | | | | | 1917 | Red clover | 1.10 | 0.74 |
| | | | | | 1918 | Grass | 0.85 | 0.64 |
| | | | | | 1922 | Red clover | 2.48 | 0.99 |
| | | | | | 1923 | Grass | 0.73 | 0.41 |
| Average | 25.9 | 1.53 | 23.9 | 1.47 | | | 1.50 | 0.91 |
| Corn | | | | | | Soybean hay | | |
| | Bu. | Tons | Bu. | Tons | | Dominating constituent | Tons | Tons |
| 1909 | 78.5 | 1.93 | 61.4 | 1.74 | 1910 | | 2.51 | 2.52 |
| 1914 | 48.8 | 2.01 | 49.1 | 2.15 | 1915 | | 2.08 | 2.08 |
| 1919 | 51.4 | 2.74 | 48.3 | 2.32 | 1920 | | 2.74 | 2.28 |
| 1924 | 40.3 | 1.21 | 39.5 | 1.26 | 1925 | | 0.85 | 0.72 |
| Average | 53.5 | 2.00 | 49.7 | 1.87 | | | 2.05 | 1.89 |

in 1920 was there a marked response. This followed the second liming, and the result was similar to that obtained with both cowpeas and soybeans following the reliming in the cowpea-wheat rotation.

It is noticeable that 2 of the 3 wheat crops were nearly as good on the unlimed section as on the limed. Only the third and last crop was decidedly better on the limed section.

The contrast between the effects of liming on the yield of the clovers, on the one hand, and of either cowpeas or soybeans, on the other, is very striking. On manured land, with similar conditions for all crops, the cowpeas showed little effect from liming; and the same is true of soybeans, except for a single season. But the clover and grass crops were nearly doubled by liming, and there is no indication of diminishing returns; the yields on the limed and unlimed sections continued to be far apart throughout the period of the experiments. If it be assumed that the effect of liming on

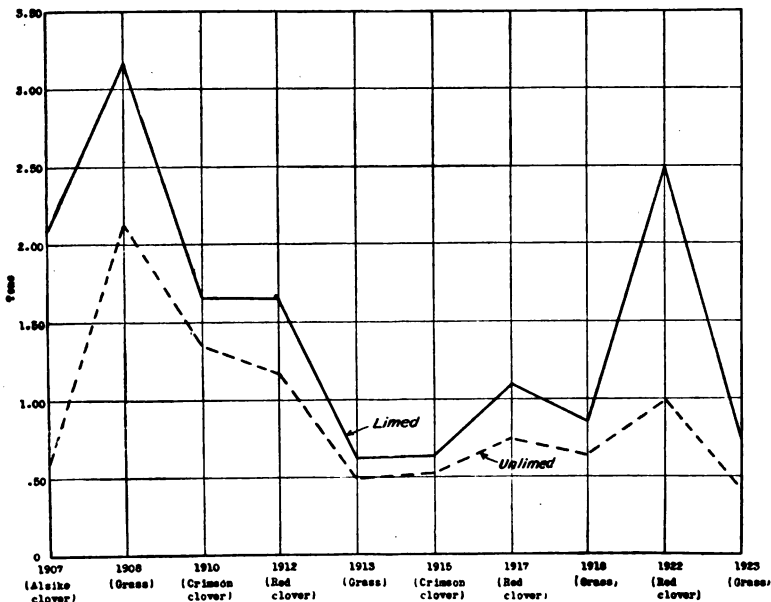


Chart 18—Yields of clover and grass hay in 5-year rotation experiments—Knoxville

the supply of available soil nitrogen was the same in one rotation as in the other, as could reasonably be expected, the conclusion is reached that liming produced larger crops of clover, at least in the latter half of the period, through some important process other than that of increasing the availability of the soil nitrogen—probably by the correction of soil acidity. It is noticeable that the second year's crop, which was chiefly grass, was not benefited by the liming to as great an extent as the first year's crop. The increase obtained may have been largely due to the clover, which furnished the major part of the crop the first year, and may well have been responsible the second year, through the decomposition of its roots and stubble, for supplying the grass with an extra amount of nitrogen.

SOIL NITROGEN DATA

Determinations of the soil nitrogen were not made throughout the period as in the cowpea-wheat experiments, but samples were taken in 1907, in 1913, and again in 1919, from both the limed and the unlimed half of each of the 15 plots. The average annual application of manure for these plots for the 14-year period amounts

to only 3¼ tons. The average percentages of soil nitrogen for each year are given in table 15. The nitrogen content of at least the 1907 sampling would fall in the period of nitrogen depression

TABLE 15—*Nitrogen content of the limed and unlimed soil of the corn, soybeans, wheat, and clover and grass rotation plots—averages from the individual analyses of 15 plots under each condition (m. f. basis).*

| Time of sampling | Cropping condition | Limed | Unlimed | Average |
|------------------|----------------------|----------|----------|----------|
| | | Per cent | Per cent | Per cent |
| Summer 1907 | Clover and grass sod | .1140 | .1134 | .1137 |
| Summer 1913 | Clover and grass sod | .1198 | .1187 | .1192 |
| Winter 1919 | Fallow after corn | .1161 | .1157 | .1159 |

on the limed portions of the cowpea-wheat plots. This depression continued to be marked in 1913 for only those plots where the cowpeas were removed. In the case of the 15 plots of the 5-year rotation there is no evidence of nitrogen depression attributable to liming in the results of any year. In fact, the nitrogen content was always a little higher in the soil of the limed sections than of the unlimed. The most noticeable result is the apparent increase in nitrogen content under both conditions as contrasted with the appreciable decline in the case of the cowpea-wheat plots where the cowpea crops were turned under, and with the very marked decline in the case of the plots where the cowpea crops were removed. This comparison is made in chart 19.

A ROTATION OF COWPEAS AND WHEAT NOT GENERALLY PRACTICABLE

With both crops grown annually on the same land, the rotation of cowpeas and wheat appears to be of practical possibility in this State only under favorable conditions. The important favorable condition at Knoxville was the fertility of the soil. On very poor soil it was found, in other trials, especially in the higher portions of the State, that the cowpea crop obtainable after wheat harvest was too small and uncertain, even when well fertilized, to justify this rotation. It is therefore recommended for consideration only in the lower and warmer sections, particularly where the conditions are favorable to the cowpea crop. It appeared feasible under the conditions at Jackson. If it proves to be so it can be utilized over a large part of West Tennessee, and the soil productivity be maintained and even increased. Attention must always be paid, however, to the possible soil need of phosphoric acid and potash, the former in particular being deficient over large areas in the State.

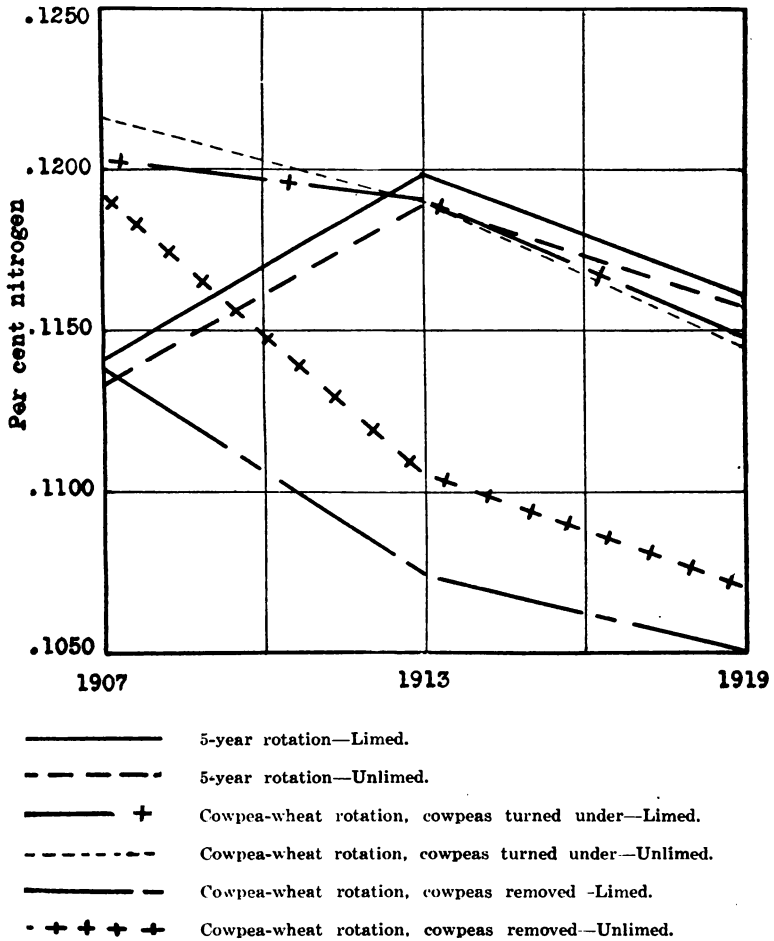


Chart 19—Changes in soil nitrogen content—Knoxville

SUMMARY

EXPERIMENTS IN A COWPEA-WHEAT ROTATION KNOXVILLE DATA

POTASH

1. The plots fertilized with 50 pounds per acre of muriate of potash produced, without exception, materially more cowpea hay than those which received no potash but were otherwise similarly treated. For the 20-year period the average annual gain attributable to the potash was 633 pounds per acre of cured hay.

2. The yield of wheat was only slightly greater on the potash-treated plots, the annual average gain per acre being 1.1 bushels of grain and .14 ton of straw. These increases may be attributed more to the larger amount of cowpea hay produced on the potash-treated plots than to the direct effect of the potash salt on wheat yield—the hay being turned under in 2 of the 3 sets.

3. Leaf mildew was pronounced on the no-potash plots, especially during the later years.

4. There was no indication that liming increased the availability of the soil potash; on the contrary there were indications of a depressive action.

5. Liming was of little effect on the cowpea crop where no potash was applied, but was highly effective in the case of the wheat crop on phosphated plots.

PHOSPHATE

1. Phosphate produced little increase of the cowpea crops, the average annual increase per acre being only 87 pounds of hay.

2. The increased yield of wheat attributable to phosphating was appreciable, the annual average for the 20 years being 2.8 bushels of grain and 160 pounds of straw per acre.

3. The soil was not considered to be sufficiently in need of phosphoric acid to make the comparison between the different phosphates used of any special value.

FARMYARD MANURE

1. Four tons per acre of manure applied annually was highly effective in increasing both the cowpea and the wheat crops. The former were greater than any obtained elsewhere, and the latter unexcelled. Each ton of manure was calculated to be worth nearly \$5.50.

2. Where the manure was applied at the time of soil preparation for the cowpea crop, 520 pounds per acre more hay was produced than where the application was delayed until the preparation for the wheat crop. Under the latter condition 1.6 bushels more

of wheat and 300 pounds more of straw per acre were obtained than under the former. The data are average annual increases for a 13-year period, and clearly indicate that the most profitable returns came from the application of manure for the cowpea crop.

3. As measured by the increase of the wheat crop, only 31.6 per cent of the nitrogen applied in the manure was recovered. With the increase of the cowpea crop included, the calculated recovery was 63.4 per cent.

EFFECTS OF LIMING ON THE YIELD OF COWPEAS

1. For the 9 years immediately following the first liming, the limed sections produced each year, as an average of all plots excepting H8, more than the unlimed, the average annual increase being 318 pounds of hay per acre. The effects were much less pronounced, however, in the case of the manure plots and of those plots where the crops were turned under, than elsewhere. For the 3 years prior to reliming, the limed and unlimed areas yielded practically alike.

2. The second liming produced decidedly less effect than the first, both as to intensity and duration. The effect was practically negligible where the crops were turned under.

3. The appearance of the growing crops, the nodule development, and the nitrogen content of the hay supplemented the data on crop yield in indicating strongly that the increased yield of cowpeas on the limed areas was due primarily to an increased supply of available soil nitrogen.

EFFECTS OF LIMING ON THE YIELD OF WHEAT

1. As an average of all plots, the first liming resulted in a marked increase in yield of wheat, continuing for the first 10 years, following which were 2 years with practically equal production on the limed and unlimed areas.

2. Where the cowpea crops were turned under the second liming was followed by increased yields on the limed areas for the 3 following years, after which the limed and unlimed areas yielded practically alike. Where the cowpea crops were removed the yields continued favorable to the limed sections.

3. As was the case with the cowpea crops, the effect of liming throughout the 20-year period was more pronounced on the yields of wheat where the cowpea crops were removed, without return of manure, and where no cowpeas were grown, than elsewhere.

INFLUENCE OF THE COWPEA CROP ON THE YIELD OF WHEAT

1. The yields of wheat were not maintained under any of the experimental conditions. Even where the cowpeas were turned un-

der annually the wheat yields continued to decline slowly for the first 14 years.

2. The average annual yield where the cowpea crops were turned under was 8 bushels per acre greater for the 20-year period than that from plots similarly fertilized but from which the cowpea crops were removed.

3. Where no cowpeas were grown and a bare fallow was maintained during the summer, the yields were among the best for the first 4 years and much better than were obtained under similar fertilizing where the cowpea crops were removed. For the last 10 years there was an average annual yield of .7 bushel per acre less than where the cowpeas were removed and 10.1 bushels less than where the cowpeas were turned under.

4. The calculated recovery of nitrogen from the cowpea crops turned under was 32.5 per cent when measured by the increased yield of wheat only, and 42.5 per cent when the increased yield of cowpea hay was included.

SOIL STUDIES

NITROGEN

1. The nitrogen content of the soil under all the experimental conditions declined appreciably for the first 10 years, after which there was little change. The averages of 4 plots where the cowpeas were removed were .1236 per cent at the outset and .1042 per cent at the end of the first 10 years. The corresponding averages for the 13 plots where the cowpeas were turned under were .1266 and .1152 per cent. At the end of the second 10 years the averages were .1029 per cent where the cowpeas were removed and .1163 per cent where they were turned under.

2. For a period of between 5 and 8 years after the first liming the limed areas where the cowpea crops were turned under showed an appreciably lower nitrogen content than the unlimed. A similar but more pronounced result was noticeable for at least 8 years where the cowpea crops were removed.

3. The correlation between the more rapid loss of soil nitrogen on the limed areas and the increased yields from the same areas is striking.

4. The limings caused little or no waste of soil nitrogen, but appear to have accelerated for a time losses of nearly equal magnitude which took place at a more nearly uniform rate where no liming was done.

TOTAL HUMUS

1. Where the cowpea crops were turned under annually there was a loss of .11 per cent, or 2,200 pounds per acre, of total humus at the end of the 20-year period.

2. Where the cowpea crops were removed annually the loss at the end of the 20-year period was .24 per cent, or 4,800 pounds per acre.

3. The turning under of 20 crops of cowpea hay containing a total of nearly 20 tons of dry substance was calculated to have left a residue of 2,600 pounds of humus.

4. The soil of the manured plots—4 tons per acre for 20 years—showed a gain of .11 per cent of humus, or 2,200 pounds per acre.

5. The effects of liming were not marked, but where the cowpea crops were removed there was at the end of the 20 years .08 per cent, or 1,600 pounds per acre, less humus in the soil of the limed than the unlimed sections. Where the cowpea crops were turned under the limed sections show a slightly higher content by .02 per cent. The results from the limed sections of the manured plots show .12 per cent, or 2,400 pounds per acre, more humus than the unlimed.

ACTIVE OR COLLOIDAL HUMUS

1. Determinations of active, or colloidal, humus were made periodically every 2 or 3 years for the first 10 years.

2. At the end of the 10-year period there was found on the average a loss of .07 per cent of colloidal humus where the cowpea crops were removed, a loss of .05 per cent where the cowpea crops were turned under, and a gain of .03 per cent for the soil of the manured plots.

3. Liming resulted in a lower content of colloidal humus noticeable under all conditions in the earlier years, with the maximum in the neighborhood of the fifth year. At the close of the tenth year no appreciable difference remained except where the cowpea crops were removed, plots G4, G5, G8, and I4; the unlimed soil containing more colloidal humus by .06 per cent, or 1,200 pounds per acre.

JACKSON DATA

EFFECTS OF LIMING ON THE YIELD OF COWPEAS

1. The response to liming was especially marked for the first 13 years, the annual average increase for the period being 860 pounds, or 44.3 per cent, of cured hay per acre. For the next 4 years the average increase was 320 pounds of hay, or only 17.8 per cent.

2. The increases attributable to liming were of similar magnitude, both where the cowpea crops were turned under and where they were removed.

EFFECTS OF LIMING ON THE YIELD OF WHEAT

1. The limed section produced larger wheat crops under all the experimental conditions. The average annual increases per acre were as follows:

3.5 bushels of grain and 600 pounds of straw where the cowpea crops were removed.

5.8 bushels of grain and 1,000 pounds of straw where the cowpea crops were turned under.

3.1 bushels of grain and 220 pounds of straw where no cowpeas were grown.

INFLUENCE OF THE COWPEA CROP ON THE YIELD OF WHEAT

1. Where no cowpeas were grown the yields of wheat show a downward trend, with an average annual yield of 15.5 bushels. Where the cowpea crops were removed the wheat crops were well maintained, with an average annual yield of 16.8 bushels. The average yield where the cowpeas were turned under was 22.3 bushels, with a tendency for the yields to increase.

2. Where the cowpea crops were removed the average production of wheat for the first 8 years was .7 bushel less than where no cowpeas were grown, but for the last 8 years it was 3.3 bushels more.

GENERAL CONCLUSIONS FROM THE LIMING DATA OF THE COWPEA-WHEAT EXPERIMENTS

1. The principal effect of liming, so far as the crops used in the cowpea-wheat experiments are concerned, was that of a stimulant, increasing the amount of soil nitrogen available for crop use. That the stimulation follows the law of diminishing returns is clearly shown in the Knoxville data, and is supported by the Jackson data, for the cowpea crop.

2. Liming with burnt lime was not found to exert permanently harmful effects on the soil, and is therefore a justifiable practice as long as the crop increases are profitable.

EXPERIMENTS IN A 5-YEAR ROTATION AT KNOXVILLE

1. Experiments in a 5-year rotation of corn, soybeans, wheat, and clover and grass, under both limed and unlimed conditions, were conducted at Knoxville for the same period, 1905-1925, and under the same soil conditions, as the cowpea-wheat experiments. The manuring and fertilizing were similar to those of the manure plots, F6 and G6, which showed little response to liming.

2. The majority of both the wheat and soybean crops failed to show any increase as the result of liming.

3. On the average, the yield of corn was 4 bushels per acre larger on the limed than on the unlimed section. This was attributed in large part to the greater residues of clover and grass on the limed section.

4. Alsike, red, and crimson clovers all showed marked response to liming, with no indication of decreasing effectiveness of liming throughout the period. The response of crimson clover was less than that of either of the other crops.

5. The increased supply of available nitrogen induced by liming appears to have been a minor factor in the case of the clovers, especially in the later years. Probably soil acidity was the dominant factor.

6. Soil samples were taken at 6-year intervals over the 12-year period from both the limed and unlimed sections of 15 plots. The general conclusions from the nitrogen determinations were as follows:

(1) The per cent of soil nitrogen was larger in 1913 and 1919 than in 1907.

(2) The nitrogen content of the soil was better maintained under the conditions of the 5-year rotation than where the cowpea crops were turned under every year in the cowpea-wheat rotation—the comparison being made over the same interval of time.

(3) The nitrogen contents of the limed sections were each year slightly larger than those of the unlimed.

THE COWPEA-WHEAT ROTATION

A rotation of cowpeas and wheat as carried out in the experiments is not advised for general use in Tennessee, but may be practicable under favorable soil and climatic conditions.

TABLE 16—Annual yields of (1) cowpea hay and (2) wheat for the individual plots of the cowpea-wheat experiments at the Knoxville Station for the 20-year period, 1905-1925.

| Plot and fertilizer treatment | Year | Cowpea hay | | | Wheat | | | | | |
|--|---------|----------------|----------------|-------------------------------|---------------|----------------|---------------|----------------|------------------------------|--------------|
| | | Limed | Un-limed | Average of limed and un-limed | Limed | | Unlimed | | Average of limed and unlimed | |
| | | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| COWPEA HAY REMOVED | | | | | | | | | | |
| F6
Manure | 1905-6 | Tons
(1.24) | Tons
(1.24) | Tons
1.24 | Bu.
(35.7) | Tons
(2.11) | Bu.
(35.7) | Tons
(2.11) | Bu.
35.7 | Tons
2.11 |
| | 1906-7 | 0.67 | 0.67 | 0.67 | 30.3 | 2.01 | 30.7 | 1.88 | 30.5 | 1.95 |
| | 1907-8 | 1.24 | 1.30 | 1.27 | 23.5 | 1.30 | 22.2 | 1.29 | 22.9 | 1.30 |
| | 1908-9 | 1.80 | 1.62 | 1.71 | 24.0 | 1.48 | 23.3 | 1.44 | 23.7 | 1.46 |
| | 1909-10 | 1.26 | 1.26 | 1.26 | 27.7 | 1.77 | 27.3 | 1.82 | 27.5 | 1.79 |
| | 1910-11 | 1.89 | 1.69 | 1.79 | 23.7 | 1.33 | 27.0 | 1.63 | 25.4 | 1.48 |
| | 1911-12 | 1.46 | 1.15 | 1.31 | 32.7 | 1.74 | 31.3 | 1.66 | 32.0 | 1.70 |
| | 1912-13 | 0.68 | 1.00 | 0.84 | 33.8 | 2.20 | 29.8 | 2.00 | 31.8 | 2.10 |
| | 1913-14 | 1.04 | 1.04 | 1.04 | 24.0 | 1.44 | 24.7 | 1.42 | 24.4 | 1.43 |
| | 1914-15 | 2.16 | 2.36 | 2.26 | 23.3 | 1.18 | 21.7 | 1.03 | 22.5 | 1.11 |
| | 1915-16 | 0.85 | 1.24 | 1.05 | 24.6 | 1.32 | 24.0 | 1.40 | 24.3 | 1.36 |
| | 1916-17 | 2.27 | 2.27 | 2.27 | 26.8 | 0.66 | 25.4 | 0.68 | 26.1 | 0.67 |
| | 1917-18 | 0.70 | 0.54 | 0.62 | 24.0 | 1.36 | 21.8 | 1.24 | 22.9 | 1.30 |
| | 1918-19 | 1.36 | 1.22 | 1.29 | 20.0 | 1.58 | 19.7 | 1.09 | 19.9 | 1.49 |
| | 1919-20 | 2.69 | 2.08 | 2.39 | 24.0 | 1.64 | 23.8 | 1.48 | 23.9 | 1.56 |
| | 1920-21 | 1.64 | 1.84 | 1.74 | 26.7 | 1.80 | 23.7 | 1.80 | 27.7 | 1.80 |
| | 1921-22 | 0.88 | 0.76 | 0.82 | 18.7 | 1.72 | 16.0 | 1.46 | 17.4 | 1.59 |
| | 1922-23 | 1.10 | 1.10 | 1.10 | 24.0 | 1.44 | 23.3 | 1.38 | 23.5 | 1.41 |
| | 1923-24 | 1.97 | 2.00 | 1.99 | 22.0 | 1.42 | 21.3 | 1.40 | 21.7 | 1.41 |
| | 1924-25 | 0.90 | 0.93 | 0.92 | 32.0 | 0.68 | 32.0 | 0.68 | 32.0 | 0.68 |
| | Average | 1.39 | 1.36 | 1.38 | 26.1 | 1.52 | 25.5 | 1.44 | 25.8 | 1.48 |
| G4
Acid phosphate | 1905-6 | (1.36) | (1.36) | 1.36 | (31.0) | (1.73) | (31.0) | (1.73) | 31.0 | 1.73 |
| | 1906-7 | 0.65 | 0.35 | 0.50 | 29.0 | 1.62 | 23.0 | 1.11 | 26.0 | 1.37 |
| | 1907-8 | 1.04 | 0.89 | 0.97 | 25.9 | 1.30 | 16.5 | .87 | 21.2 | 1.09 |
| | 1908-9 | 1.44 | 0.95 | 1.19 | 20.7 | 1.31 | 17.4 | 1.01 | 19.1 | 1.16 |
| | 1909-10 | 0.87 | 0.62 | 0.75 | 19.6 | 1.26 | 14.6 | 0.93 | 17.1 | 1.10 |
| | 1910-11 | 1.10 | 1.10 | 1.10 | 17.7 | 0.81 | 10.3 | 0.53 | 14.0 | 0.67 |
| | 1911-12 | 0.53 | 0.52 | 0.53 | 18.0 | 0.82 | 10.7 | 0.52 | 14.4 | 0.67 |
| | 1912-13 | 0.32 | 0.32 | 0.32 | 17.8 | 0.96 | 15.2 | 0.76 | 16.5 | 0.86 |
| | 1913-14 | 0.52 | 0.40 | 0.46 | 22.0 | 0.94 | 18.7 | 0.84 | 20.4 | 0.89 |
| | 1914-15 | 1.04 | 0.63 | 0.84 | 12.0 | 0.56 | 10.7 | 0.40 | 11.4 | 0.48 |
| | 1915-16 | 0.41 | 0.40 | 0.41 | 16.0 | 0.80 | 13.9 | 0.68 | 15.0 | 0.74 |
| | 1916-17 | 0.66 | 0.69 | 0.68 | 21.3 | 0.32 | 12.8 | 0.30 | 17.1 | 0.31 |
| | 1917-18 | 0.14 | 0.21 | 0.18 | 12.5 | 0.64 | 05.3 | 0.24 | 08.9 | 0.44 |
| | 1918-19 | 0.30 | 0.46 | 0.38 | 09.3 | 0.64 | 12.0 | 0.64 | 10.7 | 0.64 |
| | 1919-20 | 1.10 | 0.59 | 0.85 | 10.6 | 0.72 | 08.0 | 0.50 | 09.3 | 0.61 |
| | 1920-21 | 0.32 | 0.38 | 0.35 | 14.0 | 0.70 | 12.0 | 0.60 | 13.0 | 0.65 |
| | 1921-22 | 0.44 | 0.32 | 0.38 | 11.3 | 1.06 | 10.0 | 0.74 | 10.7 | 0.90 |
| | 1922-23 | 0.60 | 0.53 | 0.57 | 10.0 | 0.70 | 08.0 | 0.56 | 09.0 | 0.63 |
| | 1923-24 | 0.74 | 0.62 | 0.68 | 10.7 | 0.56 | 08.0 | 0.56 | 09.4 | 0.56 |
| | 1924-25 | 0.32 | 0.34 | 0.33 | 15.3 | 0.38 | 07.7 | 0.29 | 11.5 | 0.34 |
| | Average | .70 | .58 | .64 | 17.2 | .89 | 13.3 | .69 | 15.3 | .79 |
| G5
Acid phosphate
and muriate
of potash | 1905-6 | (1.52) | (1.52) | 1.52 | (30.5) | (1.57) | (30.5) | (1.57) | 30.5 | 1.57 |
| | 1906-7 | 0.80 | 0.39 | 0.60 | 24.7 | 1.30 | 20.3 | 1.39 | 22.5 | 1.35 |
| | 1907-8 | 1.25 | 0.91 | 1.08 | 21.9 | 1.30 | 16.6 | 0.87 | 19.3 | 1.09 |
| | 1908-9 | 1.42 | 1.25 | 1.34 | 18.1 | 1.11 | 17.6 | 0.98 | 17.9 | 1.05 |
| | 1909-10 | 1.48 | 1.17 | 1.32 | 21.7 | 1.15 | 14.3 | 0.97 | 18.0 | 1.06 |
| | 1910-11 | 1.66 | 1.43 | 1.55 | 18.0 | 0.90 | 15.0 | 0.79 | 16.5 | 0.85 |
| | 1911-12 | 1.05 | 0.81 | 0.93 | 19.0 | 0.87 | 17.3 | 0.80 | 18.2 | 0.84 |
| | 1912-13 | 0.60 | 0.52 | 0.56 | 17.8 | 0.80 | 16.0 | 0.80 | 16.9 | 0.80 |
| | 1913-14 | 0.92 | 0.76 | 0.84 | 17.3 | 0.92 | 17.3 | 0.92 | 17.3 | 0.92 |
| | 1914-15 | 1.80 | 1.32 | 1.56 | 12.4 | 0.55 | 11.7 | 0.57 | 12.1 | 0.56 |
| | 1915-16 | 0.88 | 0.80 | 0.84 | 15.7 | 0.68 | 15.7 | 0.72 | 15.7 | 0.70 |
| | 1916-17 | 1.07 | 1.12 | 1.09 | 17.0 | 0.47 | 15.1 | 0.45 | 16.1 | 0.46 |
| | 1917-18 | 0.38 | 0.40 | 0.39 | 15.4 | 0.33 | 06.9 | 0.43 | 11.2 | 0.63 |
| | 1918-19 | 0.70 | 0.78 | 0.74 | 10.4 | 0.62 | 10.1 | 0.63 | 10.3 | 0.63 |
| | 1919-20 | 1.34 | 1.07 | 1.46 | 12.4 | 0.76 | 12.2 | 0.64 | 12.3 | 0.70 |
| | 1920-21 | 1.01 | 1.04 | 1.03 | 15.7 | 0.90 | 14.4 | 1.00 | 15.1 | 0.95 |
| | 1921-22 | 0.80 | 0.48 | 0.64 | 11.7 | 0.78 | 11.1 | 0.88 | 11.4 | 0.83 |
| | 1922-23 | 0.96 | 0.77 | 0.87 | 11.1 | 0.72 | 09.7 | 0.72 | 10.4 | 0.72 |
| | 1923-24 | 1.26 | 0.88 | 1.07 | 12.3 | 0.68 | 11.0 | 0.66 | 11.7 | 0.67 |
| | 1924-25 | 0.58 | 0.39 | 0.49 | 14.6 | 0.42 | 11.9 | 0.34 | 13.3 | 0.38 |
| | Average | 1.10 | 0.89 | 1.00 | 16.9 | 0.87 | 14.7 | 0.81 | 15.8 | 0.84 |

TABLE 16 (Continued)

| Plot and fertilizer treatment | Year | Cowpea hay | | | Wheat | | | | | |
|--|---------|-------------|-------------|-------------------------------|------------|-------------|------------|-------------|------------------------------|-----------|
| | | Limed | Un-limed | Average of limed and un-limed | Limed | | Unlimed | | Average of limed and unlimed | |
| | | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| G6
Manure, acid phosphate and muriate of potash | 1905-6 | Tons (1.45) | Tons (1.45) | Tons 1.45 | Bu. (38.3) | Tons (1.89) | Bu. (38.3) | Tons (1.89) | Bu. 38.3 | Tons 1.89 |
| | 1906-7 | 0.67 | 0.67 | 0.67 | 27.7 | 1.69 | 32.3 | 1.87 | 30.0 | 1.78 |
| | 1907-8 | 1.57 | 1.43 | 1.50 | 24.5 | 1.30 | 21.5 | 1.16 | 23.0 | 1.23 |
| | 1908-9 | 1.75 | 1.60 | 1.67 | 23.0 | 1.47 | 21.7 | 1.27 | 22.9 | 1.37 |
| | 1909-10 | 1.69 | 1.48 | 1.59 | 27.8 | 1.80 | 26.0 | 1.80 | 26.7 | 1.80 |
| | 1910-11 | 1.47 | 1.47 | 1.47 | 25.0 | 1.33 | 21.3 | 1.06 | 23.2 | 1.20 |
| | 1911-12 | 0.94 | 0.83 | 0.89 | 35.3 | 1.82 | 30.7 | 1.76 | 33.0 | 1.79 |
| | 1912-13 | 1.20 | 1.04 | 1.12 | 31.2 | 1.40 | 25.8 | 1.60 | 28.5 | 1.50 |
| | 1913-14 | 0.92 | 0.88 | 0.90 | 25.3 | 1.28 | 22.7 | 1.32 | 24.0 | 1.30 |
| | 1914-15 | 1.81 | 1.75 | 1.78 | 23.3 | 1.10 | 24.0 | 1.12 | 23.7 | 1.11 |
| | 1915-16 | 0.92 | 1.28 | 1.10 | 22.6 | 1.32 | 21.3 | 1.24 | 22.0 | 1.28 |
| | 1916-17 | 1.76 | 1.80 | 1.78 | 29.9 | 0.74 | 27.9 | 0.72 | 28.9 | 0.73 |
| | 1917-18 | 1.34 | 1.02 | 1.18 | 25.3 | 1.08 | 19.3 | 1.04 | 22.3 | 1.06 |
| | 1918-19 | 0.93 | 0.96 | 0.95 | 23.0 | 1.43 | 21.3 | 2.00 | 22.2 | 1.72 |
| | 1919-20 | 2.59 | 2.26 | 2.43 | 19.8 | 1.02 | 17.2 | 1.00 | 18.5 | 1.01 |
| | 1920-21 | 1.64 | 1.84 | 1.74 | 26.7 | 1.50 | 24.7 | 1.40 | 25.7 | 1.45 |
| | 1921-22 | 1.08 | 1.06 | 1.07 | 16.7 | 1.34 | 16.7 | 1.22 | 16.7 | 1.28 |
| | 1922-23 | 1.26 | 1.21 | 1.24 | 21.3 | 1.36 | 18.0 | 1.18 | 19.7 | 1.27 |
| | 1923-24 | 1.86 | 1.58 | 1.72 | 21.3 | 1.28 | 20.0 | 1.28 | 20.7 | 1.28 |
| | 1924-25 | 0.74 | 0.72 | 0.73 | 33.3 | 0.76 | 28.3 | 0.71 | 30.8 | 0.74 |
| | Average | 1.38 | 1.32 | 1.35 | 26.1 | 1.35 | 24.0 | 1.33 | 25.0 | 1.34 |
| G8
Rock phosphate and muriate of potash | 1905-6 | (1.28) | (1.28) | 1.28 | (28.3) | (1.39) | (28.3) | (1.39) | 28.3 | 1.39 |
| | 1906-7 | 0.71 | 0.51 | 0.61 | 21.3 | 1.20 | 22.0 | 1.30 | 21.7 | 1.25 |
| | 1907-8 | 0.88 | 0.96 | 0.92 | 20.5 | 0.79 | 16.2 | 0.87 | 18.4 | 0.83 |
| | 1908-9 | 1.09 | 1.22 | 1.16 | 15.7 | 0.97 | 16.0 | 0.96 | 15.9 | 0.97 |
| | 1909-10 | 1.47 | 1.26 | 1.36 | 18.0 | 1.02 | 16.7 | 0.90 | 17.4 | 0.96 |
| | 1910-11 | 1.28 | 1.06 | 1.17 | 14.7 | 0.68 | 13.3 | 0.64 | 14.0 | 0.66 |
| | 1911-12 | 0.70 | 0.54 | 0.62 | 16.0 | 0.72 | 19.3 | 0.90 | 17.7 | 0.81 |
| | 1912-13 | 0.60 | 0.64 | 0.62 | 15.2 | 0.72 | 17.2 | 0.76 | 16.2 | 0.74 |
| | 1913-14 | 0.70 | 0.68 | 0.69 | 16.7 | 0.86 | 14.7 | 0.84 | 15.7 | 0.85 |
| | 1914-15 | 1.35 | 1.05 | 1.20 | 18.0 | 0.62 | 13.3 | 0.60 | 15.7 | 0.61 |
| | 1915-16 | 0.88 | 0.77 | 0.83 | 13.3 | 0.72 | 13.3 | 0.72 | 13.3 | 0.72 |
| | 1916-17 | 1.48 | 1.22 | 1.35 | 17.3 | 0.48 | 17.3 | 0.48 | 17.3 | 0.48 |
| | 1917-18 | 0.52 | 0.50 | 0.51 | 17.8 | 0.76 | 12.5 | 0.56 | 15.2 | 0.66 |
| | 1918-19 | 0.63 | 0.82 | 0.73 | 12.0 | 0.72 | 13.7 | 0.87 | 12.9 | 0.80 |
| | 1919-20 | 2.19 | 1.43 | 1.81 | 13.2 | 0.72 | 11.8 | 0.70 | 12.5 | 0.71 |
| | 1920-21 | 1.29 | 1.44 | 1.37 | 16.7 | 1.00 | 18.0 | 1.10 | 17.4 | 1.05 |
| | 1921-22 | 0.68 | 0.64 | 0.66 | 10.7 | 0.72 | 10.7 | 0.72 | 10.7 | 0.72 |
| | 1922-23 | 1.01 | 0.85 | 0.93 | 11.3 | 0.70 | 09.3 | 0.60 | 10.3 | 0.65 |
| | 1923-24 | 1.36 | 1.01 | 1.19 | 10.0 | 0.56 | 10.7 | 0.52 | 10.4 | 0.54 |
| | 1924-25 | 0.56 | 0.44 | 0.50 | 14.7 | 0.36 | 11.3 | 0.36 | 13.0 | 0.36 |
| | Average | 1.04 | 0.92 | 0.98 | 16.1 | 0.79 | 15.3 | 0.79 | 15.7 | 0.79 |
| I4
None | 1905-6 | (1.15) | (1.15) | 1.15 | (25.9) | (1.32) | (25.9) | (1.32) | 25.9 | 1.32 |
| | 1906-7 | 0.63 | 0.42 | 0.53 | 25.3 | 1.36 | 20.3 | 1.15 | 22.8 | 1.26 |
| | 1907-8 | 0.75 | 0.68 | 0.72 | 19.9 | 1.00 | 15.5 | 0.90 | 17.7 | 0.95 |
| | 1908-9 | 1.20 | 0.90 | 1.05 | 17.7 | 0.96 | 16.3 | 0.92 | 17.0 | 0.94 |
| | 1909-10 | 1.04 | 0.77 | 0.90 | 17.3 | 1.00 | 09.3 | 0.68 | 13.3 | 0.84 |
| | 1910-11 | 0.97 | 0.90 | 0.94 | 13.0 | 0.59 | 08.0 | 0.44 | 10.5 | 0.52 |
| | 1911-12 | 0.54 | 0.42 | 0.48 | 12.7 | 0.62 | 08.0 | 0.48 | 10.4 | 0.55 |
| | 1912-13 | 0.36 | 0.32 | 0.34 | 12.9 | 0.60 | 10.1 | 0.65 | 11.5 | 0.63 |
| | 1913-14 | 0.40 | 0.32 | 0.36 | 15.6 | 0.78 | 15.0 | 0.76 | 15.3 | 0.77 |
| | 1914-15 | 0.79 | 0.51 | 0.65 | 09.1 | 0.41 | 07.1 | 0.39 | 08.1 | 0.40 |
| | 1915-16 | 0.36 | 0.39 | 0.38 | 11.7 | 0.58 | 13.7 | 0.66 | 12.7 | 0.62 |
| | 1916-17 | 0.73 | 0.57 | 0.65 | 10.7 | 0.35 | 09.1 | 0.31 | 09.9 | 0.33 |
| | 1917-18 | 0.17 | 0.22 | 0.20 | 10.1 | 0.55 | 04.3 | 0.23 | 07.5 | 0.39 |
| | 1918-19 | 0.26 | 0.35 | 0.31 | 09.4 | 0.33 | 05.7 | 0.44 | 07.6 | 0.39 |
| | 1919-20 | 0.96 | 1.11 | 1.04 | 10.4 | 0.70 | 07.6 | 0.50 | 09.0 | 0.60 |
| | 1920-21 | 0.24 | 0.40 | 0.32 | 11.7 | 0.60 | 09.1 | 0.50 | 10.4 | 0.55 |
| | 1921-22 | 0.12 | 0.28 | 0.20 | 09.7 | 0.60 | 07.7 | 0.58 | 08.7 | 0.59 |
| | 1922-23 | 0.51 | 0.50 | 0.51 | 08.4 | 0.56 | 05.7 | 0.44 | 07.1 | 0.50 |
| | 1923-24 | 0.52 | 0.48 | 0.50 | 08.3 | 0.48 | 05.6 | 0.32 | 07.0 | 0.40 |
| | 1924-25 | 0.27 | 0.32 | 0.30 | 11.3 | 0.32 | 03.0 | 0.28 | 07.2 | 0.30 |
| | Average | 0.60 | 0.55 | 0.58 | 13.6 | 0.69 | 10.4 | 0.60 | 12.0 | 0.64 |

TABLE 16 (Continued)

| Plot and
fertilizer
treatment | Year | Cowpea hay | | | Wheat | | | | | |
|--|---------|----------------|----------------|---|---------------|----------------|---------------|----------------|------------------------------------|--------------|
| | | Limed | Un-
limed | Ave-
rage of
limed
and
un-limed | Limed | | Unlimed | | Average of
limed and
unlimed | |
| | | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| COWPEA HAY TURNED UNDER | | | | | | | | | | |
| F4
Acid phosphate | 1905-6 | Tons
(1.23) | Tons
(1.23) | Tons
1.23 | Bu.
(34.5) | Tons
(2.01) | Bu.
(34.5) | Tons
(2.01) | Bu.
34.5 | Tons
2.01 |
| | 1906-7 | 0.59 | 0.41 | 0.50 | 84.0 | 2.18 | 25.0 | 1.12 | 29.5 | 1.65 |
| | 1907-8 | 1.18 | 1.11 | 1.12 | 80.5 | 1.53 | 21.2 | 1.08 | 25.9 | 1.31 |
| | 1908-9 | 1.45 | 1.19 | 1.32 | 28.4 | 1.88 | 22.3 | 1.34 | 25.4 | 1.61 |
| | 1909-10 | 1.27 | 1.17 | 1.22 | 31.0 | 2.00 | 24.6 | 1.55 | 27.8 | 1.78 |
| | 1910-11 | 1.39 | 1.33 | 1.36 | 27.7 | 1.61 | 24.0 | 1.28 | 25.9 | 1.45 |
| | 1911-12 | 0.83 | 0.77 | 0.80 | 30.7 | 1.40 | 25.7 | 1.19 | 28.2 | 1.30 |
| | 1912-13 | 0.44 | 0.60 | 0.52 | 25.8 | 1.20 | 20.6 | 1.20 | 23.2 | 1.20 |
| | 1913-14 | 0.70 | 0.60 | 0.65 | 25.3 | 1.36 | 24.0 | 1.36 | 24.7 | 1.36 |
| | 1914-15 | 1.32 | 1.42 | 1.62 | 22.0 | 0.98 | 19.3 | 0.94 | 20.7 | 0.96 |
| | 1915-16 | 0.72 | 0.77 | 0.75 | 20.0 | 1.00 | 20.6 | 1.08 | 20.3 | 1.04 |
| | 1916-17 | 0.99 | 1.04 | 1.02 | 17.3 | 0.48 | 20.7 | 0.50 | 19.0 | 0.49 |
| | 1917-18 | 0.34 | 0.49 | 0.42 | 22.6 | 0.92 | 15.1 | 0.74 | 18.9 | 0.83 |
| | 1918-19 | 0.44 | 0.51 | 0.48 | 15.7 | 1.01 | 13.0 | 0.77 | 14.4 | 0.89 |
| | 1919-20 | 1.11 | 1.02 | 1.07 | 18.4 | 1.18 | 14.6 | 0.86 | 16.5 | 1.02 |
| | 1920-21 | 0.76 | 0.68 | 0.72 | 23.3 | 1.20 | 21.2 | 1.30 | 22.3 | 1.25 |
| | 1921-22 | 0.64 | 0.48 | 0.56 | 16.0 | 1.20 | 13.8 | 1.08 | 14.7 | 1.14 |
| | 1922-23 | 0.71 | 0.79 | 0.75 | 17.3 | 1.04 | 14.0 | 1.02 | 15.7 | 1.03 |
| | 1923-24 | 0.96 | 0.80 | 0.88 | 16.7 | 0.98 | 15.3 | 0.82 | 16.0 | 0.90 |
| | 1924-25 | 0.51 | 0.43 | 0.47 | 20.3 | 0.55 | 16.3 | 0.43 | 18.3 | 0.49 |
| | Average | 0.90 | 0.84 | 0.87 | 23.9 | 1.29 | 20.3 | 1.08 | 22.1 | 1.19 |
| F5
Acid phosphate
and muriate
of potash | 1905-6 | (1.43) | (1.43) | 1.43 | (36.7) | (1.99) | (36.7) | (1.99) | 36.7 | 1.99 |
| | 1906-7 | 0.64 | 0.47 | 0.56 | 30.1 | 1.86 | 27.8 | 1.65 | 29.0 | 1.76 |
| | 1907-8 | 1.08 | 0.88 | 0.98 | 27.5 | 1.37 | 22.2 | 1.13 | 24.9 | 1.25 |
| | 1908-9 | 1.66 | 1.37 | 1.52 | 27.1 | 1.72 | 25.3 | 1.57 | 26.2 | 1.65 |
| | 1909-10 | 1.68 | 1.25 | 1.46 | 28.7 | 1.98 | 26.3 | 1.67 | 27.5 | 1.83 |
| | 1910-11 | 1.84 | 1.57 | 1.71 | 26.3 | 1.65 | 27.7 | 1.63 | 27.0 | 1.64 |
| | 1911-12 | 0.82 | 0.78 | 0.80 | 31.7 | 1.61 | 30.7 | 1.56 | 31.2 | 1.59 |
| | 1912-13 | 0.96 | 0.60 | 0.78 | 27.5 | 1.58 | 26.9 | 1.64 | 27.2 | 1.61 |
| | 1913-14 | 0.96 | 0.88 | 0.92 | 28.3 | 1.52 | 25.0 | 1.58 | 26.7 | 1.55 |
| | 1914-15 | 1.95 | 1.78 | 1.87 | 23.1 | 1.15 | 25.1 | 1.21 | 24.1 | 1.18 |
| | 1915-16 | 0.84 | 1.08 | 0.96 | 21.1 | 1.10 | 21.8 | 1.18 | 21.5 | 1.14 |
| | 1916-17 | 1.42 | 1.75 | 1.59 | 19.2 | 0.61 | 21.7 | 0.90 | 20.5 | 0.76 |
| | 1917-18 | 0.72 | 0.62 | 0.67 | 24.3 | 1.31 | 15.4 | 0.95 | 19.9 | 1.13 |
| | 1918-19 | 0.71 | 1.02 | 0.87 | 20.7 | 1.43 | 18.7 | 1.01 | 19.7 | 1.22 |
| | 1919-20 | 1.77 | 1.53 | 1.65 | 22.6 | 1.04 | 21.6 | 1.18 | 22.1 | 1.11 |
| | 1920-21 | 1.18 | 1.30 | 1.24 | 27.1 | 1.60 | 27.9 | 1.60 | 27.5 | 1.60 |
| | 1921-22 | 0.76 | 0.58 | 0.67 | 16.4 | 1.40 | 16.4 | 1.32 | 16.4 | 1.36 |
| | 1922-23 | 0.99 | 0.88 | 0.94 | 17.1 | 1.22 | 21.7 | 1.40 | 19.4 | 1.31 |
| | 1923-24 | 1.32 | 1.14 | 1.23 | 15.6 | 1.06 | 17.0 | 1.06 | 16.3 | 1.06 |
| | 1924-25 | 0.57 | 0.61 | 0.59 | 22.4 | 0.55 | 22.7 | 0.54 | 22.6 | 0.55 |
| | Average | 1.17 | 1.08 | 1.12 | 24.7 | 1.39 | 23.9 | 1.34 | 24.3 | 1.37 |
| F8
Rock phosphate
and muriate
of potash | 1905-6 | (1.42) | (1.42) | 1.42 | (34.8) | (2.30) | (34.8) | (2.30) | 34.8 | 2.30 |
| | 1906-7 | 0.70 | 0.67 | 0.69 | 32.0 | 2.76 | 34.0 | 2.72 | 33.0 | 2.74 |
| | 1907-8 | 0.92 | 1.16 | 1.04 | 30.5 | 1.73 | 27.9 | 1.72 | 29.2 | 1.73 |
| | 1908-9 | 1.43 | 1.62 | 1.53 | 27.3 | 1.78 | 28.0 | 1.83 | 27.7 | 1.81 |
| | 1909-10 | 1.50 | 1.51 | 1.51 | 27.7 | 1.87 | 28.3 | 1.83 | 28.0 | 1.85 |
| | 1910-11 | 1.33 | 1.36 | 1.35 | 32.0 | 1.64 | 25.7 | 1.59 | 28.9 | 1.62 |
| | 1911-12 | 0.54 | 0.60 | 0.57 | 32.0 | 1.72 | 32.0 | 1.84 | 32.0 | 1.78 |
| | 1912-13 | 0.76 | 0.52 | 0.64 | 32.0 | 1.84 | 28.6 | 1.84 | 30.3 | 1.84 |
| | 1913-14 | 0.64 | 0.72 | 0.68 | 25.3 | 1.40 | 25.3 | 1.44 | 25.3 | 1.42 |
| | 1914-15 | 1.27 | 1.18 | 1.23 | 24.0 | 1.36 | 21.3 | 1.04 | 22.7 | 1.20 |
| | 1915-16 | 0.88 | 0.88 | 0.88 | 23.2 | 1.36 | 21.9 | 1.28 | 22.6 | 1.32 |
| | 1916-17 | 1.87 | 1.91 | 1.89 | 21.3 | 0.56 | 32.6 | 1.02 | 27.0 | 0.79 |
| | 1917-18 | 0.59 | 0.67 | 0.63 | 27.1 | 1.64 | 22.6 | 1.32 | 24.9 | 1.48 |
| | 1918-19 | 0.74 | 1.01 | 0.88 | 25.7 | 1.63 | 25.7 | 1.63 | 25.7 | 1.63 |
| | 1919-20 | 2.06 | 1.34 | 1.70 | 25.2 | 1.64 | 22.6 | 1.52 | 23.9 | 1.58 |
| | 1920-21 | 1.29 | 1.44 | 1.37 | 25.7 | 1.90 | 25.7 | 2.30 | 25.7 | 2.10 |
| | 1921-22 | 0.76 | 0.76 | 0.76 | 18.0 | 1.46 | 16.0 | 1.48 | 17.0 | 1.47 |
| | 1922-23 | 0.85 | 0.90 | 0.88 | 23.3 | 1.50 | 24.0 | 1.72 | 23.7 | 1.61 |
| | 1923-24 | 1.45 | 1.54 | 1.50 | 21.3 | 1.20 | 20.0 | 1.24 | 20.7 | 1.22 |
| | 1924-25 | 0.64 | 0.70 | 0.67 | 31.0 | 0.71 | 30.3 | 0.69 | 30.7 | 0.70 |
| | Average | 1.08 | 1.10 | 1.09 | 27.0 | 1.60 | 26.4 | 1.62 | 26.7 | 1.61 |

TABLE 16 (Continued)

| Plot and fertilizer treatment | Year | Cowpea hay | | | Wheat | | | | | |
|--|---------|-------------|-------------|-------------------------------|------------------|-------------|------------|-------------|------------------------------|-----------|
| | | Limed | Un-limed | Average of limed and un-limed | Limed | | Unlimed | | Average of limed and unlimed | |
| | | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| H4
No fertilizer | 1905-6 | Tons (1.21) | Tons (1.21) | Tons 1.21 | Bu. (34.6) | Tons (2.08) | Bu. (34.6) | Tons (2.08) | Bu. 34.6 | Tons 2.08 |
| | 1906-7 | 0.53 | 0.50 | 0.52 | 31.8 | 1.95 | 28.1 | 1.62 | 30.0 | 1.79 |
| | 1907-8 | 0.86 | 0.89 | 0.88 | 25.5 | 1.32 | 22.9 | 1.15 | 24.2 | 1.24 |
| | 1908-9 | 1.48 | 1.50 | 1.49 | 24.6 | 1.67 | 21.6 | 1.40 | 23.1 | 1.54 |
| | 1909-10 | 1.13 | 1.09 | 1.11 | 21.3 | 1.54 | 21.7 | 1.61 | 21.5 | 1.58 |
| | 1910-11 | 1.20 | 1.23 | 1.22 | 26.7 | 1.44 | 23.0 | 1.23 | 24.9 | 1.34 |
| | 1911-12 | 0.66 | 0.76 | 0.71 | 25.3 | 1.24 | 26.7 | 1.12 | 26.0 | 1.18 |
| | 1912-13 | 0.52 | 0.40 | 0.46 | 20.3 | 1.08 | 22.1 | 1.24 | 21.2 | 1.16 |
| | 1913-14 | 0.43 | 0.52 | 0.50 | 23.0 | 1.16 | 23.6 | 1.18 | 23.3 | 1.17 |
| | 1914-15 | 1.03 | 1.03 | 1.03 | 17.1 | 0.85 | 18.4 | 0.85 | 17.8 | 0.85 |
| | 1915-16 | 0.60 | 0.77 | 0.69 | 20.5 | 0.90 | 21.8 | 1.06 | 21.2 | 0.98 |
| | 1916-17 | 1.06 | 1.12 | 1.09 | 14.5 | 0.47 | 18.3 | 0.47 | 16.4 | 0.47 |
| | 1917-18 | 0.26 | 0.40 | 0.33 | 16.3 | 0.91 | 10.8 | 0.67 | 13.6 | 0.79 |
| | 1918-19 | 0.37 | 0.61 | 0.49 | 11.7 | 0.82 | 13.4 | 0.93 | 12.6 | 0.88 |
| | 1919-20 | 0.96 | 1.32 | 1.14 | 15.0 | 0.84 | 18.8 | 1.10 | 16.9 | 0.97 |
| | 1920-21 | 0.37 | 0.68 | 0.53 | 17.7 | 1.00 | 21.7 | 1.30 | 19.7 | 1.15 |
| | 1921-22 | 0.52 | 0.52 | 0.52 | 13.1 | 1.02 | 11.7 | 1.10 | 12.4 | 1.06 |
| | 1922-23 | 0.56 | 0.79 | 0.63 | 15.1 | 1.36 | 15.1 | 1.04 | 15.1 | 1.23 |
| | 1923-24 | 0.64 | 0.90 | 0.77 | 15.0 | 0.84 | 17.0 | 0.90 | 16.5 | 0.87 |
| | 1924-25 | 0.32 | 0.40 | 0.36 | 16.9 | 0.45 | 18.3 | 0.46 | 15.1 | 0.46 |
| | Average | 0.74 | 0.83 | 0.79 | 20.3 | 1.15 | 20.2 | 1.12 | 20.3 | 1.14 |
| H6
Bone meal and muriate of potash | 1905-6 | (1.27) | (1.27) | 1.27 | (34.0) | (1.99) | (34.0) | (1.99) | 34.0 | 1.99 |
| | 1906-7 | 0.59 | 0.48 | .53 | 28.0 | 1.88 | 28.3 | 1.67 | 28.2 | 1.78 |
| | 1907-8 | 1.19 | 0.86 | 1.03 | 27.7 | 1.35 | 21.3 | 1.33 | 24.5 | 1.34 |
| | 1908-9 | 1.55 | 1.01 | 1.28 | 25.3 | 1.68 | 25.7 | 1.67 | 25.5 | 1.68 |
| | 1909-10 | 1.64 | 1.17 | 1.40 | 30.0 | 2.02 | 21.3 | 1.43 | 25.7 | 1.75 |
| | 1910-11 | 1.59 | 1.10 | 1.35 | 26.7 | 1.40 | 24.7 | 1.24 | 25.7 | 1.32 |
| | 1911-12 | 0.82 | 0.70 | 0.76 | 29.3 | 1.68 | 26.7 | 1.60 | 28.0 | 1.64 |
| | 1912-13 | 0.84 | 0.36 | 0.60 | 31.2 | 1.76 | 25.8 | 1.36 | 28.5 | 1.56 |
| | 1913-14 | 1.00 | 0.80 | 0.90 | 25.3 | 1.30 | 23.3 | 1.34 | 24.3 | 1.32 |
| | 1914-15 | 1.92 | 1.02 | 1.47 | 24.7 | 1.38 | 21.3 | 1.08 | 23.0 | 1.23 |
| | 1915-16 | 0.88 | 0.80 | 0.84 | 24.0 | 1.28 | 23.2 | 1.16 | 23.6 | 1.22 |
| | 1916-17 | 1.67 | 1.39 | 1.53 | 24.1 | 0.56 | 21.3 | 0.56 | 22.7 | 0.56 |
| | 1917-18 | 0.80 | 0.54 | 0.67 | 24.0 | 1.28 | 12.0 | 0.84 | 18.0 | 1.06 |
| | 1918-19 | 0.69 | 0.93 | 0.81 | 20.0 | 1.48 | 20.7 | 1.46 | 20.4 | 1.47 |
| | 1919-20 | 1.73 | 1.40 | 1.57 | 22.6 | 1.16 | 17.2 | 0.92 | 19.9 | 1.04 |
| | 1920-21 | 1.32 | 1.34 | 1.33 | 34.0 | 2.40 | 24.0 | 1.50 | 29.0 | 1.95 |
| | 1921-22 | 0.72 | 0.60 | 0.66 | 17.3 | 1.48 | 13.3 | 1.20 | 15.3 | 1.34 |
| | 1922-23 | 1.01 | 0.79 | 0.90 | 20.0 | 1.44 | 18.0 | 1.30 | 19.0 | 1.37 |
| | 1923-24 | 1.34 | 1.00 | 1.17 | 20.0 | 1.20 | 16.0 | 1.20 | 17.0 | 1.20 |
| | 1924-25 | 0.65 | 0.62 | 0.64 | 30.0 | 0.62 | 16.7 | 0.42 | 23.4 | 0.52 |
| | Average | 1.16 | 0.91 | 1.04 | 25.9 | 1.46 | 21.7 | 1.27 | 23.8 | 1.37 |
| H8
Acid phosphate and muriate of potash | 1905 | (1.24) | (1.24) | 1.24 | (No wheat grown) | | | | | |
| | 1906 | 0.59 | 0.58 | 0.58 | | | | | | |
| | 1907 | 1.16 | 1.13 | 1.15 | | | | | | |
| | 1908 | 1.77 | 1.98 | 1.88 | | | | | | |
| | 1909 | 1.51 | 1.45 | 1.48 | | | | | | |
| | 1910 | 1.90 | 1.93 | 1.92 | | | | | | |
| | 1911 | 1.44 | 1.38 | 1.39 | | | | | | |
| | 1912 | 0.92 | 0.92 | 0.92 | | | | | | |
| | 1913 | 1.00 | 0.92 | 0.96 | | | | | | |
| | 1914 | 1.92 | 2.15 | 2.04 | | | | | | |
| | 1915 | 1.02 | 1.20 | 1.11 | | | | | | |
| | 1916 | 1.60 | 1.61 | 1.61 | | | | | | |
| | 1917 | 0.87 | 0.88 | 0.88 | | | | | | |
| | 1918 | 0.97 | 1.34 | 1.16 | | | | | | |
| | 1919 | 1.70 | 1.19 | 1.45 | | | | | | |
| | 1920 | 1.61 | 1.51 | 1.56 | | | | | | |
| | 1921 | 0.92 | 1.00 | 0.96 | | | | | | |
| | 1922 | 0.85 | 0.82 | 0.84 | | | | | | |
| | 1923 | 1.20 | 0.98 | 1.09 | | | | | | |
| | 1924 | 0.65 | 0.73 | 0.74 | | | | | | |
| | Average | 1.24 | 1.24 | 1.24 | | | | | | |

TABLE 16 (Continued)

| Plot and
fertiliser
treatment | Year | Cowpea hay | | | Wheat | | | | | |
|--|---------|------------|--------------|---|--------|--------|---------|--------|------------------------------------|-------|
| | | Limed | Un-
limed | Average
of limed
and un-
limed | Limed | | Unlimed | | Average of
limed and
unlimed | |
| | | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| 15
Acid phosphate
and potash | 1905-6 | (1.62) | (1.62) | 1.62 | (41.3) | (2.87) | (41.3) | (2.87) | 41.3 | 2.87 |
| | 1906-7 | 0.84 | 0.55 | 0.70 | 34.3 | 1.96 | 26.7 | 1.56 | 30.5 | 1.76 |
| | 1907-8 | 1.33 | 0.91 | 1.12 | 27.9 | 1.69 | 27.0 | 1.40 | 27.5 | 1.55 |
| | 1908-9 | 1.48 | 1.39 | 1.43 | 27.7 | 1.82 | 25.7 | 1.64 | 26.7 | 1.73 |
| | 1909-10 | 1.68 | 1.66 | 1.67 | 28.0 | 2.04 | 25.7 | 1.39 | 26.9 | 1.72 |
| | 1910-11 | 1.76 | 1.54 | 1.65 | 27.7 | 1.57 | 26.3 | 1.43 | 27.0 | 1.50 |
| | 1911-12 | 0.95 | 0.90 | 0.93 | 30.3 | 1.49 | 26.0 | 1.46 | 28.2 | 1.48 |
| | 1912-13 | 0.92 | 0.66 | 0.74 | 29.2 | 1.28 | 24.6 | 1.58 | 26.9 | 1.43 |
| | 1913-14 | 0.76 | 0.72 | 0.74 | 26.7 | 1.44 | 25.3 | 1.40 | 26.0 | 1.42 |
| | 1914-15 | 1.61 | 1.37 | 1.49 | 25.3 | 1.16 | 20.7 | 1.02 | 23.0 | 1.09 |
| | 1915-16 | 0.92 | 0.96 | 0.94 | 21.9 | 1.08 | 21.3 | 1.12 | 21.6 | 1.10 |
| | 1916-17 | 1.40 | 1.57 | 1.49 | 42.8 | 0.88 | 40.0 | 0.64 | 41.4 | 0.66 |
| | 1917-18 | 0.76 | 0.58 | 0.67 | 24.5 | 1.40 | 12.0 | 0.84 | 18.3 | 1.12 |
| | 1918-19 | 0.69 | 0.92 | 0.81 | 17.7 | 1.37 | 17.3 | 1.32 | 17.5 | 1.35 |
| | 1919-20 | 2.52 | 2.21 | 2.37 | 21.2 | 1.18 | 17.2 | 1.00 | 19.2 | 1.09 |
| | 1920-21 | 1.13 | 1.32 | 1.23 | 26.0 | 1.70 | 23.3 | 1.40 | 24.7 | 1.55 |
| | 1921-22 | 0.80 | 0.60 | 0.70 | 14.0 | 1.22 | 14.0 | 1.22 | 14.0 | 1.22 |
| | 1922-23 | 0.84 | 0.77 | 0.80 | 16.0 | 1.32 | 17.3 | 1.28 | 16.7 | 1.30 |
| | 1923-24 | 1.20 | 1.09 | 1.15 | 18.0 | 1.14 | 16.7 | 1.06 | 17.4 | 1.10 |
| | 1924-25 | 0.56 | 0.60 | 0.58 | 24.7 | 0.62 | 16.0 | 0.52 | 20.4 | 0.57 |
| | Average | 1.19 | 1.09 | 1.14 | 26.3 | 1.45 | 23.2 | 1.31 | 24.8 | 1.38 |
| 16
Thomas slag
and muriate
of potash | 1905-6 | (1.44) | (1.44) | 1.44 | (33.3) | (1.99) | (33.3) | (1.99) | 33.3 | 1.99 |
| | 1906-7 | 0.65 | 0.51 | 0.58 | 30.3 | 1.89 | 30.0 | 1.81 | 30.2 | 1.85 |
| | 1907-8 | 0.92 | 0.75 | 0.84 | 28.0 | 1.56 | 23.2 | 1.30 | 25.6 | 1.43 |
| | 1908-9 | 1.48 | 0.96 | 1.22 | 25.0 | 1.65 | 25.3 | 1.64 | 25.2 | 1.65 |
| | 1909-10 | 1.75 | 1.62 | 1.68 | 32.3 | 2.25 | 22.7 | 1.42 | 27.5 | 1.84 |
| | 1910-11 | 1.84 | 1.25 | 1.55 | 29.3 | 1.60 | 24.7 | 1.26 | 27.0 | 1.43 |
| | 1911-12 | 0.87 | 0.63 | 0.75 | 31.3 | 1.78 | 23.3 | 1.30 | 27.3 | 1.54 |
| | 1912-13 | 0.80 | 0.32 | 0.56 | 32.6 | 1.30 | 25.8 | 1.36 | 29.2 | 1.58 |
| | 1913-14 | 0.80 | 0.68 | 0.74 | 28.0 | 1.36 | 25.3 | 1.28 | 26.7 | 1.32 |
| | 1914-15 | 1.62 | 1.17 | 1.40 | 23.3 | 1.10 | 24.0 | 1.12 | 23.7 | 1.11 |
| | 1915-16 | 0.84 | 0.80 | 0.82 | 23.2 | 1.28 | 21.3 | 1.16 | 22.3 | 1.22 |
| | 1916-17 | 1.66 | 1.46 | 1.50 | 26.7 | 0.72 | 22.8 | 0.56 | 24.8 | 0.64 |
| | 1917-18 | 0.64 | 0.56 | 0.60 | 25.5 | 1.40 | 15.1 | 0.76 | 20.3 | 1.08 |
| | 1918-19 | 0.65 | 0.85 | 0.75 | 18.3 | 1.33 | 17.3 | 1.44 | 17.8 | 1.39 |
| | 1919-20 | 1.95 | 1.72 | 1.84 | 23.8 | 1.38 | 20.0 | 1.10 | 21.9 | 1.24 |
| | 1920-21 | 1.15 | 1.20 | 1.18 | 24.7 | 2.30 | 24.7 | 1.50 | 24.7 | 1.90 |
| | 1921-22 | 0.72 | 0.64 | 0.68 | 15.3 | 1.30 | 13.3 | 1.12 | 14.3 | 1.21 |
| | 1922-23 | 0.93 | 0.73 | 0.83 | 22.7 | 1.60 | 19.3 | 1.30 | 21.0 | 1.45 |
| | 1923-24 | 1.44 | 1.14 | 1.29 | 18.0 | 1.18 | 19.3 | 1.02 | 18.7 | 1.10 |
| | 1924-25 | 0.63 | 0.60 | 0.62 | 27.3 | 0.68 | 22.0 | 0.58 | 24.7 | 0.63 |
| | Average | 1.14 | 0.95 | 1.05 | 25.9 | 1.51 | 22.6 | 1.25 | 24.3 | 1.38 |
| 18
Rock phosphate
and muriate
of potash | 1905-6 | (1.23) | (1.23) | 1.23 | (28.2) | (1.66) | (28.2) | (1.66) | 28.2 | 1.66 |
| | 1906-7 | 0.64 | 0.53 | 0.59 | 34.3 | 2.05 | 29.3 | 1.76 | 31.8 | 1.91 |
| | 1907-8 | 1.03 | 0.91 | 0.97 | 24.5 | 1.39 | 21.9 | 1.26 | 23.2 | 1.33 |
| | 1908-9 | 1.44 | 1.39 | 1.42 | 25.0 | 1.65 | 23.3 | 1.50 | 24.2 | 1.58 |
| | 1909-10 | 1.60 | 1.44 | 1.52 | 27.8 | 1.74 | 25.0 | 1.63 | 26.2 | 1.69 |
| | 1910-11 | 1.58 | 1.59 | 1.59 | 25.0 | 1.55 | 23.0 | 1.35 | 24.0 | 1.45 |
| | 1911-12 | 0.93 | 0.84 | 0.89 | 30.0 | 1.74 | 23.0 | 1.30 | 29.0 | 1.77 |
| | 1912-13 | 0.72 | 0.40 | 0.56 | 26.6 | 1.56 | 25.3 | 1.44 | 26.2 | 1.50 |
| | 1913-14 | 0.84 | 0.80 | 0.82 | 21.3 | 1.16 | 20.7 | 1.08 | 21.0 | 1.12 |
| | 1914-15 | 1.36 | 1.15 | 1.26 | 24.7 | 1.26 | 14.0 | 1.10 | 19.4 | 1.18 |
| | 1915-16 | 0.77 | 0.76 | 0.77 | 19.2 | 1.04 | 17.9 | 1.00 | 18.6 | 1.02 |
| | 1916-17 | 1.64 | 1.26 | 1.45 | 25.4 | 0.64 | 22.8 | 0.70 | 24.1 | 0.67 |
| | 1917-18 | 0.80 | 0.56 | 0.68 | 20.5 | 1.80 | 13.5 | 0.88 | 17.0 | 1.34 |
| | 1918-19 | 0.76 | 0.88 | 0.82 | 17.3 | 1.28 | 23.0 | 1.43 | 20.2 | 1.36 |
| | 1919-20 | 1.80 | 1.66 | 1.73 | 22.2 | 1.38 | 21.2 | 1.18 | 21.7 | 1.28 |
| | 1920-21 | 1.58 | 1.30 | 1.44 | 28.0 | 1.90 | 28.7 | 1.90 | 28.4 | 1.90 |
| | 1921-22 | 0.44 | 0.64 | 0.54 | 15.3 | 1.42 | 14.7 | 1.28 | 15.0 | 1.35 |
| | 1922-23 | 0.95 | 0.78 | 0.87 | 18.7 | 1.74 | 15.3 | 1.30 | 17.0 | 1.52 |
| | 1923-24 | 1.52 | 1.18 | 1.35 | 18.7 | 1.20 | 16.0 | 1.04 | 17.4 | 1.12 |
| | 1924-25 | 0.58 | 0.52 | 0.55 | 24.7 | 0.70 | 20.7 | 0.50 | 22.7 | 0.60 |
| | Average | 1.11 | .99 | 1.05 | 23.8 | 1.44 | 21.7 | 1.29 | 22.3 | 1.37 |

TABLE 16 (Continued)

| Plot and fertilizer treatment | Year | Cowpea hay | | | Wheat | | | | | |
|--|---------|-------------|-------------|-------------------------------|------------|-------------|------------|-------------|------------------------------|-----------|
| | | Limed | Un-limed | Average of limed and un-limed | Limed | | Unlimed | | Average of limed and unlimed | |
| | | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| J4
Bone meal and muriate of potash | 1905-6 | Tons (1.48) | Tons (1.48) | Tons 1.48 | Bu. (31.4) | Tons (3.12) | Bu. (81.4) | Tons (3.12) | Bu. 31.4 | Tons 3.12 |
| | 1906-7 | 0.96 | 0.89 | 0.93 | 37.3 | 2.72 | 30.3 | 1.97 | 33.8 | 2.35 |
| | 1907-8 | 1.40 | 1.24 | 1.32 | 27.0 | 1.69 | 28.0 | 1.64 | 27.5 | 1.67 |
| | 1908-9 | 1.59 | 1.43 | 1.51 | 28.4 | 2.00 | 25.4 | 1.77 | 26.9 | 1.89 |
| | 1909-10 | 1.76 | 1.64 | 1.70 | 31.0 | 2.15 | 27.3 | 1.92 | 29.2 | 2.04 |
| | 1910-11 | 1.65 | 1.56 | 1.61 | 26.8 | 1.69 | 24.7 | 1.46 | 25.5 | 1.58 |
| | 1911-12 | 0.99 | 0.92 | 0.96 | 29.3 | 1.48 | 29.3 | 1.52 | 29.3 | 1.50 |
| | 1912-13 | 0.76 | 0.48 | 0.62 | 24.0 | 1.36 | 25.3 | 1.32 | 24.9 | 1.34 |
| | 1913-14 | 0.60 | 0.64 | 0.62 | 22.0 | 1.26 | 23.3 | 1.26 | 22.7 | 1.26 |
| | 1914-15 | 1.57 | 1.29 | 1.43 | 23.3 | 1.22 | 20.7 | 1.04 | 22.0 | 1.13 |
| | 1915-16 | 0.72 | 0.88 | 0.80 | 18.6 | 0.96 | 20.0 | 1.08 | 19.3 | 1.02 |
| | 1916-17 | 1.23 | 1.26 | 1.25 | 16.0 | 0.56 | 13.8 | 0.64 | 17.4 | 0.60 |
| | 1917-18 | 0.54 | 0.62 | 0.58 | 22.6 | 1.12 | 13.8 | 0.84 | 18.2 | 0.98 |
| | 1918-19 | 0.55 | 0.70 | 0.63 | 17.0 | 0.93 | 13.3 | 1.13 | 17.7 | 1.03 |
| | 1919-20 | 1.51 | 1.18 | 1.35 | 19.8 | 1.38 | 15.3 | 0.92 | 17.8 | 1.15 |
| | 1920-21 | 1.20 | 1.13 | 1.17 | 25.3 | 1.60 | 24.0 | 1.40 | 24.7 | 1.50 |
| | 1921-22 | 0.92 | 0.68 | 0.80 | 14.0 | 0.94 | 14.7 | 1.16 | 14.4 | 1.27 |
| | 1922-23 | 0.91 | 0.96 | 0.94 | 10.7 | 0.96 | 15.3 | 1.18 | 13.0 | 1.07 |
| | 1923-24 | 1.05 | 0.92 | 0.99 | | | 05.3 | 0.24 | | |
| | 1924-25 | 0.61 | 0.64 | 0.63 | 18.0 | 0.50 | 17.3 | 0.40 | 17.7 | 0.45 |
| | Average | 1.10 | 1.03 | 1.07 | 23.3 | 1.45 | 21.5 | 1.80 | 22.8 | 1.42 |
| J5
Rock phosphate and muriate of potash | 1905-6 | (1.40) | (1.40) | 1.40 | (32.9) | (2.18) | (32.9) | (2.18) | 32.9 | 2.18 |
| | 1906-7 | 0.75 | 0.53 | 0.64 | 33.4 | 1.60 | 28.4 | 1.75 | 30.9 | 1.68 |
| | 1907-8 | 1.07 | 1.00 | 1.04 | 27.5 | 1.42 | 24.5 | 1.81 | 26.0 | 1.37 |
| | 1908-9 | 1.49 | 1.13 | 1.31 | 24.7 | 1.73 | 26.0 | 1.71 | 25.2 | 1.72 |
| | 1909-10 | 1.87 | 1.49 | 1.68 | 30.3 | 2.15 | 23.0 | 1.92 | 26.7 | 2.04 |
| | 1910-11 | 1.68 | 1.62 | 1.65 | 27.0 | 1.63 | 25.3 | 1.32 | 26.2 | 1.48 |
| | 1911-12 | 0.93 | 0.87 | 0.90 | 28.7 | 1.66 | 22.7 | 1.52 | 25.7 | 1.59 |
| | 1912-13 | 0.72 | 0.52 | 0.62 | 30.2 | 1.61 | 26.3 | 1.40 | 28.3 | 1.51 |
| | 1913-14 | 0.64 | 0.70 | 0.67 | 24.7 | 1.34 | 22.7 | 1.24 | 23.7 | 1.29 |
| | 1914-15 | 1.60 | 1.29 | 1.45 | 22.7 | 1.12 | 20.7 | 1.06 | 21.7 | 1.09 |
| | 1915-16 | 0.84 | 0.96 | 0.90 | 20.6 | 1.16 | 21.9 | 1.16 | 21.3 | 1.16 |
| | 1916-17 | 1.33 | 1.53 | 1.46 | 25.4 | 0.60 | 22.8 | 0.68 | 24.1 | 0.64 |
| | 1917-18 | 0.76 | 0.60 | 0.68 | 24.5 | 1.45 | 13.5 | 0.88 | 19.0 | 1.17 |
| | 1918-19 | 0.60 | 0.95 | 0.78 | 18.7 | 1.32 | 20.0 | 1.48 | 19.4 | 1.40 |
| | 1919-20 | 1.79 | 1.46 | 1.63 | 22.6 | 1.32 | 18.6 | 1.12 | 20.6 | 1.22 |
| | 1920-21 | 1.11 | 1.26 | 1.19 | 29.3 | 1.80 | 26.7 | 1.60 | 28.0 | 1.70 |
| | 1921-22 | 0.76 | 0.60 | 0.68 | 16.7 | 1.34 | 15.3 | 1.26 | 16.0 | 1.30 |
| | 1922-23 | 0.94 | 0.92 | 0.93 | 21.3 | 1.44 | 20.0 | 1.40 | 20.7 | 1.42 |
| | 1923-24 | 1.35 | 1.20 | 1.28 | | | 18.0 | 1.14 | | |
| | 1924-25 | 0.70 | 0.67 | 0.69 | 23.3 | 0.63 | 23.0 | 0.51 | 25.7 | 0.56 |
| | Average | 1.12 | 1.04 | 1.08 | 25.2 | 1.44 | 22.6 | 1.33 | 24.3 | 1.39 |
| J6
Thomas slag and muriate of potash | 1905-6 | (1.54) | (1.54) | 1.54 | (33.9) | (3.03) | (33.9) | (3.03) | 33.9 | 3.03 |
| | 1906-7 | 0.73 | 0.78 | 0.76 | 32.7 | 2.38 | 34.7 | 2.44 | 33.7 | 2.41 |
| | 1907-8 | 1.26 | 1.32 | 1.29 | 30.7 | 1.64 | 29.5 | 1.64 | 30.1 | 1.64 |
| | 1908-9 | 1.59 | 1.61 | 1.60 | 28.0 | 2.16 | 29.0 | 1.97 | 28.5 | 2.07 |
| | 1909-10 | 1.71 | 1.68 | 1.69 | 30.0 | 2.10 | 27.3 | 1.98 | 28.7 | 2.04 |
| | 1910-11 | 1.71 | 1.18 | 1.45 | 29.0 | 1.57 | 26.7 | 1.40 | 27.9 | 1.49 |
| | 1911-12 | 0.97 | 0.79 | 0.88 | 27.3 | 1.90 | 26.0 | 1.54 | 26.7 | 1.72 |
| | 1912-13 | 0.63 | 0.36 | 0.52 | 31.2 | 1.80 | 22.6 | 1.40 | 26.9 | 1.60 |
| | 1913-14 | 0.60 | 0.60 | 0.60 | 23.3 | 1.26 | 21.3 | 1.16 | 22.3 | 1.21 |
| | 1914-15 | 1.27 | 1.12 | 1.20 | 23.3 | 0.94 | 20.7 | 0.98 | 22.0 | 0.96 |
| | 1915-16 | 0.84 | 0.84 | 0.84 | 21.3 | 1.16 | 17.9 | 1.04 | 19.6 | 1.10 |
| | 1916-17 | 1.35 | 1.48 | 1.42 | 21.3 | 0.60 | 20.1 | 0.56 | 20.7 | 0.58 |
| | 1917-18 | 0.54 | 0.50 | 0.52 | 18.6 | 0.92 | 10.6 | 0.72 | 14.6 | 0.82 |
| | 1918-19 | 0.56 | 0.85 | 0.71 | 21.3 | 1.24 | 16.0 | 1.36 | 18.7 | 1.30 |
| | 1919-20 | 1.60 | 1.01 | 1.31 | 22.6 | 1.48 | 17.2 | 1.00 | 19.9 | 1.24 |
| | 1920-21 | 1.00 | 0.99 | 1.00 | 24.7 | 2.00 | 20.7 | 1.40 | 22.7 | 1.70 |
| | 1921-22 | 0.72 | 0.72 | 0.72 | 14.0 | 1.30 | 11.3 | 1.12 | 12.7 | 1.21 |
| | 1922-23 | 0.81 | 0.80 | 0.81 | 19.3 | 1.38 | 17.3 | 1.23 | 18.3 | 1.33 |
| | 1923-24 | 1.30 | 1.04 | 1.17 | 18.0 | 1.30 | 14.7 | 0.84 | 16.4 | 1.07 |
| | 1924-25 | 0.52 | 0.53 | 0.53 | 21.7 | 0.63 | 14.7 | 0.52 | 18.2 | 0.58 |
| | Average | 1.07 | 0.99 | 1.03 | 24.9 | 1.54 | 21.9 | 1.37 | 23.4 | 1.46 |

TABLE 16 (Concluded)

| Plot and fertilizer treatment | Year | Cowpea hay | | | Wheat | | | | | |
|-------------------------------|---------|-------------|-------------|-------------------------------|------------|-------------|------------|-------------|------------------------------|-----------|
| | | Limed | Un-limed | Average of limed and un-limed | Limed | | Unlimed | | Average of limed and unlimed | |
| | | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| J8
Muriate of potash | 1905-6 | Tons (1.28) | Tons (1.28) | Tons 1.28 | Bu. (27.8) | Tons (1.77) | Bu. (27.8) | Tons (1.77) | Bu. 27.8 | Tons 1.77 |
| | 1906-7 | 0.73 | 0.59 | 0.66 | 80.0 | 1.98 | 26.7 | 2.00 | 28.4 | 1.99 |
| | 1907-8 | 1.01 | 0.94 | 0.98 | 23.5 | 1.42 | 19.2 | 1.34 | 21.4 | 1.38 |
| | 1908-9 | 1.45 | 1.24 | 1.35 | 24.0 | 1.60 | 21.7 | 1.35 | 22.9 | 1.48 |
| | 1909-10 | 1.71 | 1.76 | 1.73 | 27.7 | 2.01 | 24.0 | 1.68 | 25.9 | 1.85 |
| | 1910-11 | 1.52 | 1.55 | 1.54 | 23.0 | 1.81 | 20.8 | 1.11 | 21.7 | 1.21 |
| | 1911-12 | 0.84 | 0.85 | 0.85 | 22.7 | 1.24 | 21.7 | 1.39 | 22.2 | 1.32 |
| | 1912-13 | 0.80 | 0.44 | 0.62 | 21.2 | 1.36 | 20.6 | 1.32 | 20.9 | 1.34 |
| | 1913-14 | 0.64 | 0.65 | 0.65 | 21.3 | 1.20 | 18.7 | 1.04 | 20.0 | 1.12 |
| | 1914-15 | 1.45 | 1.27 | 1.36 | 22.0 | 1.06 | 13.3 | 0.84 | 17.7 | 0.95 |
| | 1915-16 | 1.00 | 1.00 | 1.00 | 18.6 | 0.72 | 17.9 | 1.08 | 18.3 | 0.90 |
| | 1916-17 | 1.73 | 1.65 | 1.69 | 22.0 | 0.64 | 20.7 | 0.66 | 21.4 | 0.65 |
| | 1917-18 | 0.58 | 0.70 | 0.64 | 20.0 | 1.24 | 09.8 | 0.76 | 14.7 | 1.00 |
| | 1918-19 | 0.80 | 0.95 | 0.88 | 14.3 | 1.09 | 17.3 | 1.72 | 15.8 | 1.41 |
| | 1919-20 | 1.76 | 2.08 | 1.92 | 21.2 | 1.36 | 19.8 | 1.40 | 20.5 | 1.38 |
| | 1920-21 | 1.48 | 1.52 | 1.50 | 23.3 | 1.70 | 27.3 | 2.30 | 25.3 | 2.00 |
| | 1921-22 | 1.06 | 0.76 | 0.91 | 14.7 | 1.42 | 12.7 | 1.28 | 13.7 | 1.35 |
| | 1922-23 | 0.94 | 1.07 | 1.01 | 19.3 | 1.58 | 19.3 | 1.50 | 19.3 | 1.54 |
| | 1923-24 | 1.32 | 1.42 | 1.37 | 17.3 | 1.08 | 18.7 | 1.08 | 18.0 | 1.08 |
| | 1924-25 | 0.51 | 0.64 | 0.58 | 25.0 | 0.61 | 22.0 | 0.58 | 23.5 | 0.60 |
| | Average | 1.13 | 1.12 | 1.13 | 21.9 | 1.32 | 20.0 | 1.31 | 21.0 | 1.32 |

NO COWPEAS GROWN

| | | | | | | | | | | |
|--|---------|-------|-------|-------|--------|--------|--------|--------|------|------|
| H5
Acid phosphate and muriate of potash | 1906 | _____ | _____ | _____ | (34.6) | (1.88) | (34.6) | (1.88) | 34.6 | 1.88 |
| | 1907 | _____ | _____ | _____ | 34.3 | 2.87 | 30.7 | 2.52 | 32.5 | 2.45 |
| | 1908 | _____ | _____ | _____ | 25.9 | 1.88 | 24.5 | 1.31 | 25.2 | 1.35 |
| | 1909 | _____ | _____ | _____ | 24.3 | 1.84 | 21.3 | 1.45 | 22.8 | 1.60 |
| | 1910 | _____ | _____ | _____ | 19.7 | 1.17 | 15.0 | 1.23 | 17.4 | 1.20 |
| | 1911 | _____ | _____ | _____ | 17.0 | 0.93 | 12.7 | 0.78 | 14.9 | 0.86 |
| | 1912 | _____ | _____ | _____ | 23.0 | 1.11 | 19.3 | 1.06 | 21.2 | 1.09 |
| | 1913 | _____ | _____ | _____ | 19.2 | 1.12 | 16.6 | 0.92 | 17.9 | 1.02 |
| | 1914 | _____ | _____ | _____ | 24.7 | 1.14 | 20.0 | 1.30 | 22.4 | 1.22 |
| | 1915 | _____ | _____ | _____ | 11.3 | 0.54 | 10.7 | 0.40 | 11.0 | 0.47 |
| | 1916 | _____ | _____ | _____ | 18.6 | 1.00 | 16.0 | 0.80 | 17.3 | 0.90 |
| | 1917 | _____ | _____ | _____ | 13.4 | 0.40 | 11.3 | 0.34 | 12.4 | 0.37 |
| | 1918 | _____ | _____ | _____ | 16.0 | 0.72 | 05.5 | 0.32 | 10.8 | 0.52 |
| | 1919 | _____ | _____ | _____ | 14.0 | 0.94 | 09.3 | 0.88 | 11.7 | 0.91 |
| | 1920 | _____ | _____ | _____ | 17.2 | 1.12 | 12.0 | 0.85 | 14.6 | 0.99 |
| | 1921 | _____ | _____ | _____ | 10.7 | 0.60 | 10.7 | 0.60 | 10.7 | 0.60 |
| | 1922 | _____ | _____ | _____ | 12.7 | 0.98 | 10.0 | 0.78 | 11.4 | 0.88 |
| | 1923 | _____ | _____ | _____ | 10.7 | 0.82 | 08.7 | 0.66 | 09.7 | 0.74 |
| | 1924 | _____ | _____ | _____ | 10.0 | 0.82 | 09.3 | 0.60 | 09.7 | 0.71 |
| | 1925 | _____ | _____ | _____ | 16.3 | 0.43 | 12.0 | 0.36 | 14.2 | 0.40 |
| | Average | _____ | _____ | _____ | 18.7 | 1.04 | 15.5 | 0.93 | 17.1 | 0.98 |

Average annual equivalents of fertilizer materials applied in the 20-year period, 1905-1925, calculated to acre basis:

| | |
|--------------------------|--|
| Plots F4 and G4: | 150 lbs. acid phosphate (16 per cent available P_2O_5) |
| Plots F5, G5, H8 and I5: | 150 lbs. acid phosphate
50 lbs. muriate of potash (50 per cent K_2O) |
| Plot F6: | 4 tons farmyard manure |
| Plot G6: | 4 tons farmyard manure
50 lbs. acid phosphate
12½ lbs. muriate of potash |
| Plots F8, G8, I8 and J4: | 285 lbs. rock phosphate (29.5 per cent total P_2O_5)
50 lbs. muriate of potash |
| Plots H4 and I4: | None |
| Plots H6 and J4: | 100 lbs. bone meal (25.4 per cent total P_2O_5)
50 lbs. muriate of potash |
| Plots I6 and J6: | 140 lbs. Thomas slag meal (18 per cent total P_2O_5)
50 lbs. muriate of potash |
| Plot J8: | 50 lbs. muriate of potash |

TABLE 17—*Nitrogen content of both the limed and unlimed soil of the individual plots where the cowpea crops were (1) removed and (2) turned under annually—Knoxville experiments.*

(All samples taken to a depth of 8 inches. Results on m. f. basis of the fine earth of less than $\frac{1}{2}$ mm.)

| Plot | Year | Nitrogen content | | | Plot | Year | Nitrogen content | | |
|------|------|------------------|---------|---------|------|------|------------------|---------|---------|
| | | Limed | Unlimed | Average | | | Limed | Unlimed | Average |

| COWPEAS REMOVED | | | | | | | | | |
|-----------------|------|----------|----------|----------|----|------|----------|----------|----------|
| G4 | 1905 | Per cent | Per cent | Per cent | G5 | 1905 | Per cent | Per cent | Per cent |
| | 1907 | *(.1314) | (.1314) | .1314 | | 1907 | (.1300) | (.1300) | .1300 |
| | 1910 | .1254 | .1198 | .1226 | | 1907 | .1172 | .1269 | .1221 |
| | 1910 | .1191 | .1191 | .1191 | | 1910 | .1153 | .1209 | .1181 |
| | 1913 | .1130 | .1085 | .1108 | | 1913 | .1158 | .1172 | .1165 |
| | 1915 | .1084 | .1061 | .1072 | | 1915 | .1102 | .1088 | .1095 |
| | 1917 | .1081 | .1056 | .1068 | | 1917 | .1094 | .1097 | .1096 |
| | 1919 | .1105 | .1071 | .1088 | | 1919 | .1112 | .1105 | .1108 |
| | 1922 | † | | | | 1922 | | | |
| | 1925 | .1045 | .1032 | .1039 | | 1925 | .1076 | .1088 | .1082 |
| G8 | 1905 | (.1101) | (.1101) | .1101 | I4 | 1905 | (.1236) | (.1236) | .1236 |
| | 1907 | .1019 | .1098 | .1059 | | 1907 | .1111 | .1202 | .1157 |
| | 1910 | .1027 | .1052 | .1040 | | 1910 | .1080 | .1175 | .1128 |
| | 1913 | .0994 | .1055 | .1024 | | 1913 | .1017 | .1112 | .1064 |
| | 1915 | .0972 | .0974 | .0978 | | 1915 | .1001 | .1049 | .1025 |
| | 1917 | .1012 | .1025 | .1018 | | 1917 | .0991 | .1027 | .1009 |
| | 1919 | .1010 | .1044 | .1027 | | 1919 | .0973 | .1059 | .1016 |
| | 1922 | | | | | 1922 | | | |
| | 1925 | .0986 | .1022 | .1004 | | 1925 | .0961 | .1017 | .0989 |

| COWPEAS TURNED UNDER | | | | | | | | | |
|----------------------|------|---------|---------|-------|----|------|---------|---------|-------|
| F4 | 1905 | (.1293) | (.1293) | .1293 | F5 | 1905 | (.1329) | (.1329) | .1329 |
| | 1907 | .1212 | .1202 | .1207 | | 1907 | .1226 | .1313 | .1269 |
| | 1910 | .1179 | .1165 | .1172 | | 1910 | .1223 | .1290 | .1256 |
| | 1913 | .1226 | .1172 | .1199 | | 1913 | .1229 | .1290 | .1260 |
| | 1915 | .1183 | .1150 | .1166 | | 1915 | .1208 | .1278 | .1243 |
| | 1917 | .1150 | .1183 | .1166 | | 1917 | .1271 | .1246 | .1259 |
| | 1919 | .1142 | .1129 | .1136 | | 1919 | .1228 | .1244 | .1236 |
| | 1922 | | | | | 1922 | | | |
| | 1925 | .1134 | .1137 | .1136 | | 1925 | .1230 | .1271 | .1251 |
| F8 | 1905 | (.1321) | (.1321) | .1321 | H4 | 1905 | (.1284) | (.1284) | .1284 |
| | 1907 | .1280 | .1273 | .1277 | | 1907 | .1171 | .1235 | .1203 |
| | 1910 | .1209 | .1317 | .1263 | | 1910 | .1113 | .1153 | .1135 |
| | 1913 | .1297 | .1298 | .1297 | | 1913 | .1133 | .1211 | .1172 |
| | 1915 | .1227 | .1280 | .1229 | | 1915 | .1090 | .1169 | .1130 |
| | 1917 | .1282 | .1239 | .1260 | | 1917 | .1099 | .1176 | .1138 |
| | 1919 | .1269 | .1203 | .1236 | | 1919 | .1081 | .1165 | .1123 |
| | 1922 | | | | | 1922 | | | |
| | 1925 | .1264 | .1195 | .1230 | | 1925 | .1088 | .1174 | .1131 |
| H6 | 1905 | (.1178) | (.1178) | .1178 | H8 | 1905 | (.1037) | (.1037) | .1037 |
| | 1907 | .1198 | .1204 | .1201 | | 1907 | .0977 | .1027 | .1002 |
| | 1910 | .1136 | .1166 | .1151 | | 1910 | .0946 | .1006 | .0976 |
| | 1913 | .1158 | .1150 | .1154 | | 1913 | .0974 | .0971 | .0973 |
| | 1915 | .1170 | .1100 | .1135 | | 1915 | .0901 | .0942 | .0921 |
| | 1917 | .1165 | .1158 | .1162 | | 1917 | .0942 | .0959 | .0950 |
| | 1919 | .1167 | .1130 | .1143 | | 1919 | .0947 | .0995 | .0971 |
| | 1922 | | | | | 1922 | | | |
| | 1925 | .1264 | .1195 | .1230 | | 1925 | .0986 | .0991 | .0989 |
| I5 | 1905 | (.1330) | (.1330) | .1330 | I6 | 1905 | (.1290) | (.1290) | .1290 |
| | 1907 | .1280 | .1255 | .1167 | | 1907 | .1232 | .1177 | .1204 |
| | 1910 | .1219 | .1261 | .1240 | | 1910 | .1197 | .1202 | .1200 |
| | 1913 | .1281 | .1236 | .1258 | | 1913 | .1183 | .1216 | .1200 |
| | 1915 | .1238 | .1191 | .1214 | | 1915 | .1211 | .1147 | .1179 |
| | 1917 | .1236 | .1211 | .1224 | | 1917 | .1190 | .1163 | .1179 |
| | 1919 | .1193 | .1208 | .1201 | | 1919 | .1157 | .1137 | .1147 |
| | 1922 | | | | | 1922 | | | |
| | 1925 | .1210 | .1215 | .1213 | | 1925 | .1154 | .1163 | .1161 |

TABLE 17 (Concluded)

| Plot | Year | Nitrogen content | | | Plot | Year | Nitrogen content | | |
|------|------|------------------|------------------|----------------|---|------|------------------|------------------|----------------|
| | | Limed | Unlimed | Average | | | Limed | Unlimed | Average |
| I8 | 1905 | Per cent (.1082) | Per cent (.1082) | Per cent .1082 | J4 | 1905 | Per cent (.1321) | Per cent (.1321) | Per cent .1321 |
| | 1907 | .1098 | .1069 | .1084 | | 1907 | .1219 | .1329 | .1274 |
| | 1910 | .1027 | .1092 | .1060 | | 1910 | .1149 | .1250 | .1199 |
| | 1913 | .1068 | .1077 | .1072 | | 1913 | .1211 | .1217 | .1214 |
| | 1915 | .1058 | .1018 | .1038 | | 1915 | .1124 | .1191 | .1158 |
| | 1917 | .1058 | .1056 | .1057 | | 1917 | .1142 | .1198 | .1170 |
| | 1919 | .1041 | .1033 | .1037 | | 1919 | .1117 | .1165 | .1141 |
| | 1922 | | | | | 1922 | | | |
| | 1925 | .1091 | .0961 | .1026 | | 1925 | .1129 | .1159 | .1144 |
| J5 | 1905 | (.1346) | (.1346) | .1346 | J6 | 1905 | (.1422) | (.1422) | .1422 |
| | 1907 | .1310 | .1291 | .1300 | | 1907 | .1278 | .1269 | .1273 |
| | 1910 | .1241 | .1250 | .1246 | | 1910 | .1236 | .1241 | .1239 |
| | 1913 | .1281 | .1263 | .1272 | | 1913 | .1271 | .1259 | .1265 |
| | 1915 | .1285 | .1215 | .1225 | | 1915 | .1234 | .1213 | .1223 |
| | 1917 | .1224 | .1231 | .1228 | | 1917 | .1221 | .1200 | .1211 |
| | 1919 | .1223 | .1208 | .1216 | | 1919 | .1226 | .1165 | .1196 |
| | 1922 | | | | | 1922 | | | |
| | 1925 | .1235 | .1215 | .1225 | | 1925 | .1215 | .1195 | .1205 |
| J8 | 1905 | (.1219) | (.1219) | .1219 | *In 1905, sample taken to represent whole plot; i. e., samples of limed and unlimed halves not taken separately.
†In 1922, samples taken as usual, but through oversight were rendered of questionable value by long exposure in paper bags. | | | | |
| | 1907 | .1170 | .1183 | .1177 | | | | | |
| | 1910 | .1163 | .1148 | .1155 | | | | | |
| | 1913 | .1188 | .1120 | .1154 | | | | | |
| | 1915 | .1129 | .1105 | .1117 | | | | | |
| | 1917 | .1175 | .1106 | .1140 | | | | | |
| | 1919 | .1137 | .1132 | .1135 | | | | | |
| | 1922 | | | | | | | | |
| | 1925 | .1200 | .1169 | .1185 | | | | | |

COWPEA-WHEAT ROTATION

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TABLE 18—Annual yields per acre of (1) cowpea hay and (2) wheat for the various areas of the cowpea-wheat experiments at the Jackson Station for the 16-year period 1909-1925.

| Disposition of cowpea crop | Year | Cowpea hay | | | Wheat | | | | | |
|--|---------|------------|-----------|-------------------------------|----------|-----------|----------|-----------|------------------------------|-----------|
| | | Limed | Un-limed | Average of limed and un-limed | Limed | | Unlimed | | Average of limed and unlimed | |
| | | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| Area C
Cowpea hay removed each year
(Plots 10-16) | 1909-10 | Tons 1.15 | Tons 0.73 | Tons 0.94 | Bu. 13.7 | Tons 2.16 | Bu. 06.8 | Tons 1.03 | Bu. 10.3 | Tons 1.60 |
| | 1910-11 | 1.15 | 0.81 | 0.98 | 15.3 | 1.88 | 07.5 | 1.33 | 11.4 | 1.61 |
| | 1911-12 | 2.11 | 1.67 | 1.89 | 27.8 | 1.56 | 21.5 | 1.35 | 24.7 | 1.46 |
| | 1912-13 | 1.23 | 0.70 | 0.97 | 19.3 | 1.04 | 15.2 | 0.89 | 17.3 | 0.97 |
| | 1913-14 | 1.50 | 1.09 | 1.30 | 14.9 | 0.72 | 13.2 | 0.73 | 14.1 | 0.78 |
| | 1914-15 | 1.55 | 1.46 | 1.51 | 18.2 | 0.72 | 18.1 | 0.86 | 18.2 | 0.79 |
| | 1915-16 | 1.21 | 0.83 | 1.02 | 07.5 | 0.52 | 10.3 | 0.69 | 08.9 | 0.61 |
| | 1916-17 | 0.94 | 0.55 | 0.75 | 22.5 | 0.87 | 15.4 | 0.68 | 19.0 | 0.78 |
| | 1917-18 | 1.68 | 1.40 | 1.54 | 19.4 | 0.91 | 16.4 | 0.69 | 17.9 | 0.80 |
| | 1918-19 | 1.50 | 1.13 | 1.32 | 14.0 | 0.71 | 13.8 | 0.67 | 13.9 | 0.69 |
| | 1919-20 | 1.61 | 1.08 | 1.35 | 17.5 | 0.96 | 14.5 | 0.63 | 16.0 | 0.80 |
| | 1920-21 | 1.09 | 0.71 | 0.90 | 22.9 | 1.58 | 16.9 | 0.98 | 19.9 | 1.28 |
| | 1921-22 | 1.26 | 0.78 | 1.02 | 18.7 | 1.31 | 17.5 | 1.08 | 18.1 | 1.20 |
| | 1922-23 | 0.50 | 0.42 | 0.46 | 21.6 | 1.37 | 18.9 | 1.03 | 20.3 | 1.20 |
| | 1923-24 | 0.72 | 0.61 | 0.67 | 23.2 | 1.79 | 17.9 | 0.96 | 20.6 | 1.38 |
| | 1924-25 | 0.98 | 0.72 | 0.83 | 19.0 | 1.09 | 16.6 | 0.86 | 17.8 | 0.98 |
| | 1925 | 1.53 | 1.26 | 1.40 | | | | | | |
| | Average | 1.27 | 0.94 | 1.11 | 18.5 | 1.20 | 15.0 | 0.90 | 16.8 | 1.05 |
| Area A
Cowpea hay turned under each year
(Plots 1-7) | 1909-10 | 1.15 | 0.73 | 0.94 | 12.0 | 1.81 | 06.9 | 1.04 | 09.5 | 1.43 |
| | 1910-11 | 1.25 | 0.83 | 1.04 | 16.2 | 2.25 | 10.2 | 1.54 | 13.2 | 1.90 |
| | 1911-12 | 2.05 | 1.60 | 1.83 | 30.0 | 1.74 | 24.0 | 1.43 | 27.0 | 1.59 |
| | 1912-13 | 1.55 | 0.88 | 1.22 | 27.0 | 1.80 | 19.0 | 1.21 | 23.0 | 1.51 |
| | 1913-14 | 1.46 | 1.13 | 1.30 | 24.0 | 1.34 | 17.2 | 0.96 | 20.6 | 1.15 |
| | 1914-15 | 1.80 | 1.60 | 1.70 | 30.4 | 1.74 | 26.8 | 1.41 | 28.4 | 1.58 |
| | 1915-16 | 1.59 | 0.96 | 1.28 | 13.4 | 1.13 | 11.1 | 0.88 | 12.3 | 1.01 |
| | 1916-17 | 1.23 | 0.85 | 1.04 | 32.3 | 1.63 | 24.3 | 1.13 | 28.3 | 1.38 |
| | 1917-18 | 1.88 | 1.22 | 1.55 | 32.2 | 1.67 | 26.4 | 1.22 | 29.3 | 1.45 |
| | 1918-19 | 1.83 | 1.28 | 1.56 | 21.1 | 1.40 | 18.2 | 1.07 | 18.7 | 1.24 |
| | 1919-20 | 1.92 | 1.02 | 1.47 | 25.9 | 1.86 | 19.3 | 1.12 | 22.6 | 1.49 |
| | 1920-21 | 1.50 | 0.90 | 1.20 | 27.3 | 2.39 | 18.3 | 1.59 | 23.3 | 1.99 |
| | 1921-22 | 1.52 | 1.05 | 1.29 | 28.4 | 2.16 | 22.7 | 1.72 | 25.6 | 1.94 |
| | 1922-23 | 0.81 | 0.66 | 0.74 | 28.7 | 2.10 | 19.4 | 1.40 | 21.6 | 1.75 |
| | 1923-24 | 1.01 | 0.81 | 0.91 | 30.5 | 1.86 | 23.9 | 1.37 | 27.2 | 1.62 |
| | 1924-25 | 1.30 | 1.05 | 1.18 | 25.7 | 1.82 | 21.8 | 1.57 | 23.8 | 1.70 |
| | 1925 | 1.42 | 1.29 | 1.36 | | | | | | |
| | Average | 1.49 | 1.05 | 1.27 | 25.0 | 1.79 | 19.3 | 1.29 | 22.2 | 1.64 |
| Area E
Cowpea hay turned under each year
(Plots 19-25) | 1909-10 | 1.15 | 0.73 | 0.94 | 12.7 | 1.90 | 07.3 | 1.10 | 10.0 | 1.50 |
| | 1910-11 | 1.31 | 0.86 | 1.09 | 18.1 | 2.25 | 7.9 | 1.27 | 13.0 | 1.76 |
| | 1911-12 | 2.02 | 1.74 | 1.88 | 27.9 | 1.65 | 21.0 | 1.37 | 24.5 | 1.51 |
| | 1912-13 | 1.70 | 0.91 | 1.31 | 28.9 | 1.80 | 20.3 | 1.27 | 24.6 | 1.54 |
| | 1913-14 | 1.53 | 1.18 | 1.36 | 25.9 | 1.50 | 18.3 | 1.14 | 22.1 | 1.32 |
| | 1914-15 | 1.80 | 1.60 | 1.70 | 32.9 | 1.50 | 24.3 | 1.14 | 28.6 | 1.32 |
| | 1915-16 | 1.34 | 1.03 | 1.19 | 12.8 | 1.13 | 09.3 | 0.77 | 11.1 | 0.95 |
| | 1916-17 | 1.56 | 0.84 | 1.20 | 30.5 | 1.57 | 24.2 | 1.10 | 27.4 | 1.34 |
| | 1917-18 | 2.01 | 1.31 | 1.91 | 29.0 | 1.53 | 26.0 | 1.24 | 27.5 | 1.39 |
| | 1918-19 | 1.52 | 1.09 | 1.31 | 19.8 | 1.21 | 21.3 | 1.26 | 20.6 | 1.24 |
| | 1919-20 | 1.41 | 1.04 | 1.23 | 25.7 | 1.69 | 18.0 | 1.00 | 21.9 | 1.35 |
| | 1920-21 | 1.49 | 1.00 | 1.25 | 31.9 | 2.56 | 22.4 | 1.56 | 27.2 | 2.06 |
| | 1921-22 | 1.70 | 1.21 | 1.46 | 24.7 | 2.17 | 21.8 | 1.49 | 23.3 | 1.83 |
| | 1922-23 | 0.79 | 0.68 | 0.74 | 26.7 | 1.80 | 20.1 | 1.35 | 23.4 | 1.58 |
| | 1923-24 | 1.08 | 0.94 | 1.01 | 31.8 | 2.05 | 24.2 | 1.37 | 28.0 | 1.71 |
| | 1924-25 | 1.20 | 0.92 | 1.06 | 26.9 | 1.86 | 24.8 | 1.54 | 25.9 | 1.70 |
| | 1925 | 1.44 | 1.42 | 1.43 | | | | | | |
| | Average | 1.47 | 1.12 | 1.30 | 25.4 | 1.76 | 19.5 | 1.25 | 22.4 | 1.51 |

TABLE 18 (Concluded)

| Disposition of
cowpea crop | Year | Cowpea hay | | | Wheat | | | | | |
|--|---------|------------|--------------|---|-------|-------|---------|-------|------------------------------------|-------|
| | | Limed | Un-
limed | Average of
limed and
un-
limed | Limed | | Unlimed | | Average of
limed and
unlimed | |
| | | | | | Grain | Straw | Grain | Straw | Grain | Straw |
| Area B
No cowpeas
grown
(Plots 8 and 9) | 1909-10 | Tons | Tons | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons |
| | 1910-11 | | | | 14.8 | 2.22 | 7.2 | 1.08 | 11.0 | 1.65 |
| | 1911-12 | | | | 20.7 | 2.64 | 13.0 | 2.18 | 16.9 | 2.41 |
| | 1912-13 | | | | 25.7 | 1.25 | 19.0 | 1.22 | 22.4 | 1.24 |
| | 1913-14 | | | | 23.2 | 1.76 | 21.3 | 1.54 | 22.3 | 1.65 |
| | 1914-15 | | | | 16.0 | 0.88 | 16.7 | 1.10 | 16.4 | 0.99 |
| | 1915-16 | | | | 22.3 | 1.08 | 19.0 | 0.98 | 20.7 | 1.03 |
| | 1916-17 | | | | 10.0 | 0.78 | 8.0 | 0.70 | 9.0 | 0.74 |
| | 1917-18 | | | | 23.0 | 1.01 | 14.3 | 0.71 | 18.7 | 0.86 |
| | 1918-19 | | | | 19.7 | 0.95 | 17.7 | 0.84 | 17.7 | 0.90 |
| | 1919-20 | | | | 12.7 | 0.92 | 12.0 | 0.84 | 12.4 | 0.88 |
| | 1920-21 | | | | 16.3 | 0.93 | 13.0 | 0.79 | 14.7 | 0.86 |
| | 1921-22 | | | | 18.7 | 1.48 | 10.7 | 1.04 | 14.7 | 1.26 |
| | 1922-23 | | | | 17.2 | 1.49 | 13.7 | 0.93 | 15.5 | 1.24 |
| | 1923-24 | | | | 20.7 | 1.47 | 15.4 | 1.14 | 18.1 | 1.31 |
| | 1924-25 | | | | 23.3 | 1.63 | 16.0 | 1.27 | 19.7 | 1.43 |
| | Average | | | | 14.7 | 0.88 | 14.7 | 0.88 | 14.7 | 0.88 |
| Area D
No cowpeas
grown
(Plots 17 and 18) | 1909-10 | | | | 18.6 | 1.34 | 14.5 | 1.08 | 16.6 | 1.21 |
| | 1910-11 | | | | 18.6 | 2.29 | 12.0 | 1.97 | 12.8 | 2.13 |
| | 1911-12 | | | | 21.5 | 2.23 | 10.0 | 1.55 | 15.8 | 1.92 |
| | 1912-13 | | | | 16.9 | 1.07 | 23.2 | 1.09 | 20.1 | 1.08 |
| | 1913-14 | | | | 21.9 | 1.46 | 21.4 | 1.41 | 21.7 | 1.44 |
| | 1914-15 | | | | 15.8 | 0.90 | 14.1 | 0.90 | 14.7 | 0.90 |
| | 1915-16 | | | | 18.1 | 0.98 | 16.7 | 0.77 | 17.4 | 0.85 |
| | 1916-17 | | | | 5.6 | 0.51 | 7.9 | 0.68 | 6.8 | 0.60 |
| | 1917-18 | | | | 15.7 | 0.61 | 10.2 | 0.47 | 13.0 | 0.54 |
| | 1918-19 | | | | 18.6 | 1.10 | 19.3 | 1.10 | 19.0 | 1.10 |
| | 1919-20 | | | | 8.7 | 0.58 | 9.1 | 0.63 | 8.9 | 0.61 |
| | 1920-21 | | | | 12.4 | 0.77 | 9.1 | 0.65 | 10.8 | 0.71 |
| | 1921-22 | | | | 16.1 | 0.78 | 9.1 | 0.87 | 12.6 | 0.83 |
| | 1922-23 | | | | 15.7 | 1.46 | 14.9 | 1.07 | 15.3 | 1.27 |
| | 1923-24 | | | | 14.9 | 1.20 | 11.1 | 0.97 | 13.0 | 1.09 |
| | 1924-25 | | | | 19.8 | 1.33 | 15.2 | 1.24 | 17.5 | 1.29 |
| | Average | | | | 10.3 | 1.64 | 11.1 | 0.80 | 10.7 | 1.22 |
| | | | | | 15.3 | 1.18 | 13.4 | 1.01 | 14.4 | 1.10 |

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In the Jackson series the Superintendent of the West Tennessee Station, S. A. Robert, has supervised the plot experiments in a most creditable manner.

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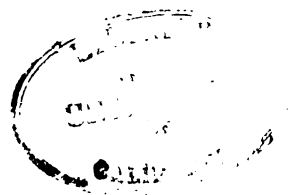
THE OAT CROP

By
C. A. MOOERS
Director and Agronomist



Grain field at Cherokee Farm, Knoxville Station

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Bulletins of this Station will be sent, upon request, free of charge, to any farmer in the State.

THE OAT CROP

By

C. A. MOOERS

Director and Agronomist

IMPORTANCE

Oats rank third in importance of the cereals grown in Tennessee. According to the reports of the U. S. Department of Agriculture, the average annual acreage in the State for the 5-year period 1921-1925 was 218,400, with an average yield of 20.7 bushels per acre. Much of the crop, however, is not threshed, but fed in the sheaf or as hay. The estimated value of the crop varied from \$2,300,000.00 to over \$3,000,000.00, the average for the period being \$2,625,000.00.

WINTER VERSUS SPRING OATS

Most of the crop is sown in early spring, and is known as spring oats, as distinguished from fall-sown, or "winter" oats. Winter damage of the latter is not uncommon, and comes from freezing and thawing weather, which causes the plants to be thrown out of the soil; from extreme cold weather; and from the attacks of aphids, which may be abundant during mild weather, even in midwinter. These insects also attack spring oats, sometimes severely. In 1907 both February and March plantings at the Knoxville Station farm were destroyed by them. Soils that heave badly in the winter are not well suited to winter oats. Partly for this reason and partly because they do not fit into the cropping system, they are little grown in the Central Basin section. On the other hand, winter oats are successfully and not uncommonly grown in some of the Highland Rim counties and in portions of East Tennessee.

On account of the lateness at which cotton and corn are usually harvested, it is customary to follow them with spring oats rather than winter oats. This seems to account for the prevalence of spring oats in West Tennessee, where soil and climatic conditions are more favorable to winter oats than elsewhere in the State.

WINTER OATS OUTYIELD SPRING OATS

Table 1 gives the comparative yields of spring and winter oats for 10 years in trials at the Knoxville Station. The evidence is highly favorable to winter oats, which made an average yield of 41.1 bushels of grain and 0.95 ton of straw per acre, in comparison with 33.6 bushels of grain and .64 ton of straw for spring oats. This comparison does not take into consideration the practically complete failure of winter oats in both 1917 and 1924, because such failures

mean in farm practice minor and not complete losses, on account of the readiness with which spring reseeds can be made.

TABLE 1—*Spring versus winter oats—trials at the Knoxville Station*

| Year of harvest | Yields per acre | | | |
|-----------------|-------------------------------|-------|--|-------|
| | Spring oats
(chiefly Burt) | | Winter oats
(Culberson and Grey Turf) | |
| | Grain | Straw | Grain | Straw |
| | Bu. | Tons | Bu. | Tons |
| 1902 | 61.3 | 1.02 | 68.0 | 1.69 |
| 1903 | 25.0 | 0.63 | 65.4 | 2.57 |
| 1911 | 14.9 | 0.37 | 21.1 | 0.59 |
| 1912 | 47.7 | 0.83 | 50.8 | 0.66 |
| 1913 | 22.5 | 0.43 | 35.9 | 0.56 |
| 1915 | 23.1 | 0.60 | 33.0 | 0.58 |
| 1916 | 20.3 | 0.50 | 24.1 | 0.70 |
| 1921 | 23.9 | 0.41 | 25.8 | 0.67 |
| 1925 | 58.1 | 1.11 | 18.8 | 0.30 |
| 1926 | 39.1 | 0.52 | 68.0 | 1.14 |
| 10-year av. | 33.6 | 0.64 | 41.1 | 0.95 |

WINTER OATS EARLIER THAN SPRING OATS

A further advantage of winter oats is that they mature earlier than spring oats. At the Knoxville Station farm the earliest and best spring varieties were harvested, on the average, about June 22. Culberson, Red Rust Proof, and Appler when fall-sown were harvested nearly two weeks earlier, or about June 8. Even the Virginia Grey Turf, which is the latest of all, matures nearly a week earlier, or about June 15.

SPRING OATS

Accurate data as to the proportions of winter and spring oats grown in this State are not available, but according to G. L. Morris, U. S. Department of Agriculture Statistician, at Nashville, winter oats constitute only from 10 to 25 per cent of the total crop, the former figure being a high estimate for the acreage sown in the fall of 1926. It is evident, therefore, that spring oats are by far the more important crop. They have, moreover, practically no competitor among the cereals that can be sown at that season of the year.

VARIETAL TRIALS

COMMENTS ON THE VARIETIES

For many years Burt was the standard spring variety in this State. It is supposed to have been brought to the Central Basin of Middle Tennessee from Alabama in the 80's. It then spread gradually over the State, and for many years was recognized both by the farmers and by the Experiment Station as the best variety for spring planting. It was rust- and smut-resistant, extra early, and less apt to be injured by the dry weather of May than a later variety, such as Red Rust Proof. Until recently the Station had tried only one other



Varietal trial of oats at the Knoxville Station

variety which appeared to be somewhat more desirable than Burt, and that was the Kherson, which had found favor in some of the northern and western states. Kherson was almost as early as Burt and more nearly uniform in character; the grain weighed better to the bushel, and the acre yield was equally good. Its favorable qualities were not sufficient, however, to cause it to displace Burt. In fact, little effort was made to bring it to the farmers' attention. About 1912 the farmers of Georgia were beginning to grow a winter oat known as Fulghum. It proved to be a high-yielding and attractive variety and soon became popular. By 1920 it was recognized as a high-yielding spring oat by the Kansas Station, which has distributed a superior strain under the name of Kanota.

TABLE 2—*Varietal trials of spring oats—Fulghum versus Burt—at the Knoxville Station*

| Year | Date of seeding | Date of harvest | Yields per acre | | | |
|---------------------|-----------------|-----------------|-----------------|-----------|----------|-----------|
| | | | Fulghum | | Burt | |
| | | | Grain | Straw | Grain | Straw |
| 1921 | Mar. 4 | June 18 | Bu. 23.9 | Tons 0.41 | Bu. 17.2 | Tons 0.44 |
| 1922 | Feb. 22 | June 12 | 12.7 | 0.47 | 10.3 | 0.42 |
| 1924 | Mar. 4 | June 28 | 47.7 | 0.78 | 38.7 | 0.97 |
| 1925 | Mar. 6 | June 17 | 48.2 | 0.91 | 34.1 | 0.97 |
| 1926 | Mar. 5 | July 2 | 39.1 | 0.52 | 28.9 | 0.55 |
| 5-year average..... | | | 34.3 | 0.62 | 25.8 | 0.67 |

FULGHUM SUPERIOR TO BURT

Although Fulghum survives most of our winters, it is not a reliable variety for fall seeding in Tennessee, but as a spring oat it has proved to be outstanding and is gaining rapidly in popularity. Table 2 gives the yields of Fulghum in comparison with Burt for a 5-year period at the Knoxville Station; the two varieties having been grown under like conditions of soil and seeding. The striking result is shown that Fulghum far outclassed Burt in yield every year, without exception; the average annual yield of Fulghum being 34.3 bushels per acre, while that of Burt was only 25.8 bushels.

In 1926 a series of trials of spring oats was made at the Middle Tennessee Station, at Columbia. Burt, Kherson, and Kanota (the Kansas strain of Fulghum) were included. The trial was made in triplicate; that is, there were 3 sets of plots from which comparisons could be made with equal fairness. The results are as follows:

| | Bushels per acre |
|---------|------------------|
| Burt | 19.3 |
| Kherson | 22.8 |
| Kanota | 28.4 |
| Fulghum | 27.5 |

As in the Knoxville trials, Fulghum gave an appreciably higher yield than either Burt or Kherson; the average for these 2 varieties being 21.1 bushels, as compared with 28.0 bushels for the average of Kanota and Fulghum.



Oat field at the Columbia Station

KANOTA A SUPERIOR STRAIN OF FULGHUM

The Fulghum oat is a well-defined variety, but like most varieties it can be separated into strains, which would be expected to differ in value. Kanota is claimed by the Kansas Station to be a superior strain under their conditions. It has been tested in comparison with southern-grown Fulghum for 3 years at the Knoxville Station and one year at the Columbia Station. The yields are given in table 3.

TABLE 3—*Varietal trials of spring oats—Kanota versus Fulghum*

| Place | Date of seeding | Yields per acre | | | |
|-----------|-----------------|-----------------|-----------|----------|-----------|
| | | Kanota | | Fulghum | |
| | | Grain | Straw | Grain | Straw |
| Knoxville | Mar. 4, 1924 | Bu. 54.3 | Tons 0.94 | Bu. 47.7 | Tons 0.78 |
| Knoxville | Mar. 6, 1925 | 56.1 | 0.99 | 52.9 | 1.04 |
| Knoxville | Mar. 5, 1926 | 39.1 | 0.54 | 39.1 | 0.52 |
| Columbia | Jan. 26, 1926 | 28.4 | ..... | 27.5 | ..... |
| Average.. | ..... | 44.5 | 0.82 | 41.8 | 0.78 |

The average yield of Kanota for the 3-year trial at Knoxville and the one year at Columbia was 44.5 bushels per acre, whereas the average for common Fulghum was only 41.8 bushels. Although a longer term of trials would be desirable, the evidence must be construed as favorable to Kanota, which at this time can be obtained in commercial quantity and makes a desirable source of seed for use in Tennessee.

HOME-GROWN VERSUS WESTERN-GROWN SEED

Experiments designed to furnish information as to the comparative merits of home-grown and western-grown seed oats were begun at the Knoxville Station in 1908, in cooperation with the Office of Cereal Investigations of the U. S. Department of Agriculture. A single lot of Rust Proof oats was bought from a Knoxville seedsman in the spring of that year. This lot was divided into three parts. One part was sent away to be grown at the Texas Experiment Station at Amarillo, another was sent to the Arkansas Station at Fayetteville, and the third was kept for seeding at the Knoxville Station. In the spring of the following year seed grown in each of the three places was planted under the same conditions at the Knoxville Station. Thereafter for a total of 8 years, seed from both of these places was planted along with home-grown seed. The yields are given in table 4.

TABLE 4—Yields per acre of Red Rust Proof oats from seed grown in three different states—trials at the Knoxville Station. (Original seed in 1908 the same for all three places)

| Year | Sources of seed and yields per acre | | | | | | Remarks |
|-----------|-------------------------------------|-------|-----------------|-------|--------------------|-------|---|
| | Knoxville, Tenn. | | Amarillo, Texas | | Fayetteville, Ark. | | |
| | Grain | Straw | Grain | Straw | Grain | Straw | |
| | Bu. | Tons | Bu. | Tons | Bu. | Tons | |
| 1909 | 23.3 | 0.73 | 21.9 | 0.63 | 23.4 | 0.65 | Yield from Fayetteville seed reduced by smut, which appeared for the first time in the 1912 crop. |
| 1910 | 35.2 | 0.83 | 33.3 | 0.75 | 29.7 | 0.80 | |
| 1911 | 11.5 | 0.30 | 14.1 | 0.33 | 12.7 | 0.30 | |
| 1912 | 44.2 | 0.92 | 46.1 | 0.91 | 35.6 | 0.97 | |
| 1913 | 18.8 | 0.40 | 18.8 | 0.48 | 12.5 | 0.35 | |
| 1914 | 9.4 | 0.34 | 8.2 | 0.32 | 6.7 | 0.27 | |
| 1915 | 22.6 | 0.66 | 26.1 | 0.65 | 21.1 | 0.60 | |
| 1916 | 22.7 | 0.62 | 22.7 | 0.55 | 16.3 | 0.65 | |
| 8-yr. av. | 23.5 | 0.60 | 23.9 | 0.58 | 19.9 | 0.57 | |

Although the conditions under which the oats were grown in Amarillo, Texas, were widely different from those at Knoxville, the yields from seed derived from the two sources were almost identical, and there was no indication of any change in either habit of growth or time of maturity. The seed from the Fayetteville Station gave an appreciably lower yield than the others, but this was probably due to the fact that it became badly infected with smut, which was noticeably present for the first time in 1912, and which was abundant thereafter in seed from this source.

Kanota, the Kansas strain of Fulghum, was found, as previously shown, to be superior to common Fulghum. This result is considered to be due to a difference in strain or variety rather than to the source of the seed.

The experimental evidence, therefore, indicates that in time of scarcity of home-grown seed western- or southern-grown seed may be safely substituted.



Harvesting 50 bushels to the acre of Fulghum oats at the Columbia Station

DATE OF PLANTING SPRING OATS

Date-of-planting trials of spring oats were conducted for 9 years at the Knoxville Station. The main object was to get the comparative yields from early and medium-late plantings. Owing to the variations in the seasonal conditions of different years, it was found to be impossible to make the plantings at any fixed date. As a rule, the early plantings were made as soon as the soil and weather conditions would allow after January. The late plantings were then made the middle of March, or as soon thereafter as possible. There is a rather wide range in the dates from year to year, but the results as given in table 5 are considered to be fairly indicative of the average expectancy.

TABLE 5—*Date-of-planting trials of spring oats at the Knoxville Station*

| Year | Date of early planting | Yield per acre of early planting | | Date of late planting | Yield per acre of late planting | |
|----------------|------------------------|----------------------------------|-----------|-----------------------|---------------------------------|-----------|
| | | Grain | Straw | | Grain | Straw |
| 1900 | Mar. 12 | Bu. 29.4 | Tons 1.20 | Apr. 2 | Bu. 22.8 | Tons 0.98 |
| 1903 | Mar. 20 | 25.0 | 0.63 | Apr. 2 | 14.1 | 0.30 |
| 1906 | Feb. 20 | 27.4 | 0.61 | Mar. 12 | 36.0 | 0.80 |
| 1908 | Feb. 29 | 26.2 | 0.62 | Mar. 16 | 26.2 | 0.65 |
| 1909 | Mar. 1 | 22.9 | 0.48 | Mar. 17 | 23.7 | 0.77 |
| 1910 | Mar. 4 | 47.2 | 1.28 | Mar. 17 | 38.9 | 0.73 |
| 1911 | Feb. 25 | 13.1 | 0.33 | Mar. 16 | 15.0 | 0.34 |
| 1913 | Feb. 1 | 10.7 | 0.30 | Mar. 20 | 18.8 | 0.44 |
| 1915 | Mar. 2 | 24.8 | 0.65 | Mar. 24 | 21.9 | 0.63 |
| 9-year average | | 25.2 | 0.68 | ..... | 24.2 | 0.63 |

DISCUSSION OF THE DATA

The dates of the early plantings varied from February 1 to March 20, and of the late plantings from March 12 to April 2. The average yield for the 9-year period was 25.2 bushels of grain and .68

ton of straw per acre for the early plantings and 25.2 bushels of grain and .63 ton of straw for the late plantings. Analysis of the data indicates, however, that extra early planting is inadvisable; the average yield for the 4 years when the early planting was made in February being only 19.4 bushels per acre, as compared with 24.0 bushels for the March plantings of those years. On the other hand, the early March plantings made for 5 years gave an annual average yield of 29.9 bushels per acre, as compared with 24.3 bushels for the later plantings of the same years.

EXTRA EARLY PLANTING SHOULD BE AVOIDED

Both experience and observation bear out the conclusion that there is considerable risk in planting extra early, or, say, any time before the first of March at Knoxville. Earlier plantings may, of course, be advisable in the warmer parts of the State, but on the Cumberland Plateau and at similar elevations seeding may well be delayed until the middle of March. The chief danger from extra early planting lies in the failure to get a full and uniform stand, because of delayed germination and decay of the seed.

WINTER OATS

Winter oats have a strong competitor in winter barley. The facts are that on land of good quality barley is much superior as a grain producer, and the beardless winter varieties now available produce larger and better hay crops. Also barley is superior for pasture purposes and fits better into farm practice because it can be sown somewhat later. Wheat and rye are competitors which are widely grown and utilized for winter pasture as well as grain. They have the advantage of being the hardiest of the small grains and of not requiring the early seeding which is important to both oats and barley.



A heavy crop at the Jackson Station

VARIETAL TRIALS

COMMENTS ON THE VARIETIES

The standard winter oat is the Virginia Grey Turf. It is recognized as hardy, uniform in type, but late in maturing, and as producing a large amount of straw in proportion to grain. In the varietal trials, a good strain of Grey Turf, known as Snoma, was used at Knoxville and at Jackson. The Culberson oat used was the short-growing strain obtained by selection at the Knoxville Station some

twenty years ago. This variety is better adapted to fertile land than the Grey Turf because much less liable to lodge; also it is ten days or more earlier, which is of decided advantage. In winter hardiness, it is considered to be on an equality with Grey Turf. A third variety was the Yellow Peruvian, which was included because of the attention it attracted at the State Fair on account of the plumpness and high weight per bushel of the grain. Fulghum was included originally because of its being widely advertised as a valuable winter oat in the South, but its hardiness under Tennessee conditions was seriously questioned.

TABLE 6—*Varietal trials of winter oats at the Jackson Station*

| Year of harvest | Date of seeding | Varieties and yields per acre | | | | | | | |
|------------------------------|-----------------|-------------------------------|-------|-------|-------|-----------|-------|-----------------|-------|
| | | Fulghum | | Snoma | | Culberson | | Yellow Peruvian | |
| | | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw |
| | | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons |
| 1915 | Oct. 18 | 27.5 | 0.37 | 42.5 | 0.92 | 49.3 | 0.98 | 38.1 | 0.59 |
| 1916 | Sept. 10 | 32.8 | 0.87 | 33.1 | 0.87 | 34.4 | 0.69 | 27.5 | 0.50 |
| 1917 | Sept. 20 | 27.5 | 0.47 | 25.0 | 0.66 | 22.5 | 0.54 | 21.8 | 0.59 |
| 1918 | Sept. 19 | 68.1 | 1.61 | 67.2 | 1.59 | 80.6 | 1.53 | 78.1 | 1.71 |
| 1919 | Sept. 14 | 38.8 | 1.00 | 30.4 | 1.19 | 38.1 | 0.87 | 27.5 | 0.89 |
| 1920 | Sept. 26 | 21.3 | 0.70 | 36.6 | 0.84 | 38.8 | 0.66 | 30.6 | 0.81 |
| 1921 | Sept. 16 | 33.8 | 1.87 | 50.0 | 1.70 | ... | ... | 38.8 | 1.18 |
| 1922 | Sept. 12 | 40.6 | 0.97 | 33.8 | 0.98 | 28.1 | 0.61 | 38.1 | 0.97 |
| 1923 | Sept. 19 | 60.6 | 1.43 | 46.3 | 1.42 | 39.7 | 1.18 | ... | ... |
| 1924 | Sept. 17 | 36.9 | 0.84 | 57.5 | 1.36 | 48.8 | 0.72 | ... | ... |
| Average... | | 38.3 | 1.01 | 42.2 | 1.15 | 41.7 | 0.86 | 37.6 | 0.90 |
| Comparative Av. of Snoma†... | | 42.2 | 1.15 | ... | ... | 41.4 | 1.09 | 40.0 | 1.09 |

TABLE 7—*Varietal trials of winter oats at the Knoxville Station*

| Year of harvest | Date of seeding | Varieties and yields per acre | | | | | |
|------------------------------------|-----------------|-------------------------------|-------|-------|-------|-----------|-------|
| | | Fulghum | | Snoma | | Culberson | |
| | | Grain | Straw | Grain | Straw | Grain | Straw |
| | | Bu. | Tons | Bu. | Tons | Bu. | Tons |
| 1911 | Oct. 5 | .... | .... | 31.7 | 0.90 | 36.1 | 0.70 |
| 1912 | Oct 25 | .... | .... | 41.0 | 0.96 | 50.8 | 0.66 |
| 1914 | ..... | .... | .... | 43.2 | 1.07 | 44.6 | 0.84 |
| 1915 | Sept. 28 and | | | | | | |
| | Oct. 9 | .... | .... | 30.8 | 0.62 | 41.0 | 0.64 |
| 1916 | Sept. 25 | 19.5 | 0.44 | 22.2 | 0.82 | 28.0 | 0.70 |
| 1917* | Oct. 2 | .... | .... | .... | .... | .... | .... |
| 1918 | Sept. 26 | .... | .... | 15.6 | 0.50 | 9.4 | 0.29 |
| 1919 | Sept. 21 | .... | .... | 24.6 | 0.93 | 22.2 | 0.20 |
| 1920 | Oct. 9 | .... | .... | 18.0 | 0.68 | 17.2 | 0.40 |
| 1921 | Oct. 1 | 17.2 | 0.56 | 21.5 | 0.56 | 16.0 | 0.63 |
| 1922 | Sept. 29 | 5.0 | 0.35 | 6.7 | 0.42 | 10.8 | 0.64 |
| 1923 | Sept. 28 | 15.7 | 0.32 | 21.5 | 0.52 | 9.0 | 0.20 |
| 1924* | Oct. 16 | .... | .... | .... | .... | .... | .... |
| 1925 | Oct. 18 | 18.8 | 0.30 | 17.2 | 0.30 | 14.5 | 0.21 |
| 1926 | Sept. 28 | 61.7 | 0.89 | 72.8 | 1.39 | 66.1 | 0.97 |
| Average | | 23.0 | 0.48 | 28.2 | 0.74 | 28.1 | 0.55 |
| Comparative average of Snoma†..... | | 26.9 | 0.67 | .... | .... | 28.2 | 0.74 |

*Winterkilled

†In the comparisons shown in tables 6 and 7 the averages of Snoma are taken for the 10, 9, 8, and 6 years, respectively, that the other varieties were grown.

DISCUSSION OF THE DATA

Table 6 gives the results obtained at the Jackson Station with all 4 varieties for the 10-year period 1915 to 1924, inclusive. Table 7 gives the data obtained at the Knoxville Station for 15 years, in two of which, 1917 and 1924, no data were obtained because of winterkilling. In this series, only Snoma (Virginia Grey Turf) and Culberson were included for the entire period, and the yields of the third variety, Fulghum, were obtained for the 6 years.

RESULTS AT THE JACKSON STATION

Winter oats have done especially well at the Jackson Station, the soil and climatic conditions being favorable. That part of the State would be selected as best suited to the less hardy varieties, such as Rust Proof, Appler, Yellow Peruvian, and Fulghum. It is of interest to note, therefore, that Fulghum as a winter oat did not yield as well as Snoma. The 10-year average for Snoma was 42.2 bushels per acre, but Fulghum under the same conditions of season, soil, and planting averaged only 38.3 bushels. In a 9-year trial Culberson and Snoma gave almost an identical average yield of a fraction over 41 bushels of grain to the acre, but Snoma produced more straw by 460 pounds per acre. The Yellow Peruvian was outyielded by Snoma in an 8-year trial to the extent of 2.4 bushels of grain and 380 pounds of straw per acre.

RESULTS AT THE KNOXVILLE STATION

At the Knoxville Station Fulghum as a winter oat proved to be inferior to Snoma; the 6-year average yield for the 2 varieties being 23.0 bushels of grain and .48 ton of straw per acre for Fulghum and 26.9 bushels of grain and .67 ton of straw for Snoma. As in the Jackson trials, Culberson and Snoma produced practically identical yields of grain, but Snoma produced more straw by 380 pounds per acre.

DATE OF PLANTING WINTER OATS

Table 8 gives the results of date-of-planting trials at the Knoxville Station for 8 years. The data are assembled by half-months, beginning the first of September and extending into November. In some respects the evidence is quite satisfactory. September seedings proved to be the best without question; the 8 seedings made the latter half of the month outyielding, on the average, the same number of seedings made the first half of October by 5.2 bushels of grain per acre. Also the seedings made the first half of October outyielded those made the latter half of that month in 4 of the 6 trials. In fact, one of the seedings made in late October failed completely. Two of the 5 seedings made the first week in November were failures, and only inferior yields were obtained at best. Although September proved to be the best month for seeding winter oats in these trials,

much more evidence would be required to prove which part of the month is better on the average; but in farm practice the latter half of the month would appear to be the more convenient time.

TABLE 8—*Date-of-planting trials of winter oats at the Knoxville Station (Varieties used: Culberson and Virginia Grey Turf)*

| Year of harvest | Dates of planting and yields per acre | | | | | | | | | |
|------------------------------------|---------------------------------------|----------|-------------|-----------|-----------|-----------|------------|-----------|----------|-----------|
| | Sept. 1-15 | | Sept. 16-30 | | Oct. 1-15 | | Oct. 16-31 | | Nov. 1-7 | |
| | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw |
| 1902 | Bu. Not sown | Tons ... | Bu. 69.8 | Tons 2.26 | Bu. 50.0 | Tons 1.70 | Bu. 39.7 | Tons 1.25 | Bu. 38.2 | Tons 1.25 |
| 1903 | 62.5 | 1.50 | 73.4 | 1.87 | 37.5 | 0.90 | Failed | ... | Failed | ... |
| 1904 | 70.3 | 2.20 | 58.6 | 2.51 | 64.1 | 2.98 | 59.4 | 3.06 | Failed | ... |
| 1906 | Not sown | ... | 56.8 | 2.07 | 50.0 | 1.80 | 58.8 | 2.42 | 26.9 | 0.49 |
| 1909 | 20.6 | 0.59 | 27.5 | 0.82 | 25.0 | 0.75 | 25.3 | ... | ... | ... |
| 1910 | 33.8 | 1.36 | 15.6 | 0.62 | 42.5 | 1.64 | 19.4 | 0.80 | 7.5 | 0.36 |
| 1914 | Not sown | ... | 47.1 | 0.96 | 40.1 | 1.02 | Not sown | ... | Not sown | ... |
| 1915 | Not sown | ... | 35.1 | 0.71 | 33.0 | 0.58 | Not sown | ... | Not sown | ... |
| Average | 46.8 | 1.41 | 48.0 | 1.48 | 42.8 | 1.42 | 40.5 | 1.88 | 24.5 | 0.70 |
| Comparative yields for Sept. 16-30 | 43.8 | 1.46 | ... | ... | 48.0 | 1.48 | 50.3 | 1.87 | 54.8 | 1.87 |

Table 9 gives the results of 12 years, 1913-1924, of date-of-planting trials at the Jackson Station. The growing season at Jackson is longer and the average temperature higher than at Knoxville;

TABLE 9—*Date-of-planting trials of winter oats at the Jackson Station (Culberson variety)*

| Year of harvest | Dates of planting and yields per acre | | | | | | | |
|----------------------------------|---------------------------------------|-----------|-----------|-----------|------------|-----------|----------|-----------|
| | Sept. 15-30 | | Oct. 1-15 | | Oct. 16-31 | | Nov. 1-7 | |
| | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw |
| 1913 | Bu. 64.0 | Tons 1.43 | Bu. 60.0 | Tons 1.18 | Bu. 27.0 | Tons 0.58 | Bu. 50.6 | Tons 1.23 |
| 1914 | 17.5 | 1.27 | 22.5 | 2.16 | 31.2 | 1.25 | 42.5 | 2.00 |
| 1915 | 46.8 | 1.11 | 17.5 | 0.29 | 33.7 | 0.60 | Not sown | ... |
| 1916 | 37.8 | 1.03 | 27.5 | 0.64 | 38.1 | 0.77 | Not sown | ... |
| 1917 | 41.2 | 0.75 | 52.5 | 1.08 | 71.2 | 1.05 | Failed | ... |
| 1918 | 80.6 | 1.53 | 108.8 | 2.04 | 85.3 | 1.33 | 69.4 | 1.11 |
| 1919 | 30.0 | 0.75 | 32.2 | 0.84 | Not sown | ... | 43.8 | 0.75 |
| 1920 | 31.3 | 0.50 | 37.5 | 0.72 | Not sown | ... | Failed | ... |
| 1921 | 27.5 | 0.90 | 26.3 | 1.00 | 37.2 | 1.27 | Not sown | ... |
| 1922 | 37.5 | 0.84 | 36.3 | 0.82 | 66.4 | 1.29 | 45.0 | 1.44 |
| 1923 | 53.1 | 1.28 | 61.9 | 1.10 | 66.2 | 1.57 | 39.4 | 1.77 |
| 1924 | 36.3 | 0.70 | 61.3 | 1.20 | Failed | ... | Not sown | ... |
| Average | 42.0 | 1.01 | 45.4 | 1.09 | 45.6* | 0.97 | 36.3 | 1.04 |
| Comparative yields for Oct. 1-15 | 45.4 | 1.09 | ... | ... | 47.5 | 1.15 | 51.5 | 1.24 |

*Failed crop included.

hence, it is not surprising that seedings made there the first half of October are the best. They are found to produce on the average 3.4 bushels of grain per acre more than seedings made the latter half of

September and 1.9 bushels more than seedings made the latter half of October. It should be noted, however, that the majority of the seedings made the latter half of October were superior to the earlier seedings, and that only the failure of the late October seeding for the 1924 crop brings the average below that for the first half of the month. Apparently, any time in October is highly favorable, but the rapid falling off of the yields obtained from early November seedings indicates that very late October seedings should be avoided if possible.

RATE OF PLANTING OF WINTER OATS

Rate-of-planting experiments with fall-sown oats were carried out for 9 years at the Jackson Station. The data are given in table 10.

TABLE 10—*Rate-of-seeding trials with fall-sown oats at the Jackson Station*

| Year of
harvest | Rates of seeding and yields per acre | | | | | | | | | | | |
|---------------------------|--------------------------------------|-------|---------|-------|---------|-------|---------|-------|----------|-------|----------|-------|
| | 2 pecks | | 4 pecks | | 6 pecks | | 8 pecks | | 10 pecks | | 12 pecks | |
| | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw |
| | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons | Bu. | Tons |
| 1916 | ... | ... | 38.1 | 0.61 | 36.8 | 0.55 | 35.0 | 0.64 | 25.9 | 0.48 | 26.8 | 0.63 |
| 1917 | ... | ... | 31.8 | 0.57 | 31.8 | 0.60 | 33.7 | 0.54 | 43.1 | 0.75 | 41.2 | 0.72 |
| 1918 | 50.6 | 0.94 | 56.6 | 1.02 | 56.6 | 1.08 | 56.6 | 1.10 | 50.6 | 1.00 | 58.6 | 1.23 |
| 1919 | 51.8 | 1.11 | 56.3 | 1.29 | 63.0 | 1.33 | 57.4 | 1.27 | 47.3 | 1.00 | 51.8 | 1.15 |
| 1920 | 36.0 | 0.65 | 49.5 | 0.79 | 53.5 | 0.86 | 36.0 | 0.50 | 36.0 | 0.50 | 45.0 | 0.79 |
| 1921 | 38.3 | 1.18 | 42.8 | 1.18 | 33.8 | 0.93 | 36.0 | 0.93 | 40.5 | 1.00 | 40.5 | 1.08 |
| 1922 | 49.5 | 1.26 | 56.3 | 1.04 | 50.6 | 1.17 | 49.5 | 1.15 | 45.0 | 1.08 | 45.0 | 1.00 |
| 1923 | 72.0 | 1.65 | 81.0 | 1.73 | 58.5 | 1.44 | 87.8 | 1.86 | 63.0 | 1.80 | 67.5 | 1.47 |
| 1925 | 43.8 | 0.94 | 48.1 | 0.98 | 52.5 | 1.16 | 61.3 | 1.22 | 65.6 | 1.19 | 65.6 | 1.19 |
| Average | 48.9 | 1.10 | 51.2 | 1.02 | 49.1 | 1.01 | 50.4 | 1.02 | 46.3 | 0.98 | 49.1 | 1.03 |
| 4-peck
rate
1918-25 | 55.8 | 1.15 | | | | | | | | | | |

The rates varied from 2 to 12 pecks per acre. The rather surprising result obtained was that the 4-peck rate gave, on the average, as good a yield as any higher rate. On the other hand, the 7-year average yield for the 2-peck rate was 6.9 bushels of grain per acre less than that of the 4-peck rate.

Although a seeding of only a bushel to the acre proved to be ample in these trials, attention may well be paid to the fact that the experiments were conducted under favorable soil and climatic conditions, which undoubtedly would admit of a low rate of seeding. Under less favorable conditions a greater loss of stand during the winter and early spring would be expected. For these reasons from 1½ to 2 bushels of seed per acre may be nearer the right amount for average conditions throughout the State.

COMBINATIONS OF ALFALFA, CLOVER AND GRASS

WITH WINTER OATS

The early seeding desirable for winter oats comes at a time that is favorable for clover and grass, so that all may be sown together. If successful, the resultant crop is most valuable for hay, the clover making a large part of the crop. For use in this way, oats are considered superior to either wheat or rye, which are generally planted too late for clover to be sown with them in the fall. If clover and grass are to be sown with the oats, the seeding should be as early as possible in September. Early and thorough soil preparation, and especially a good moisture supply at seeding time, are highly important. If the soil be dry, light showers may germinate the clover and grass seed, but the stand may be greatly reduced or even lost before sufficient rain comes. A good rule is not to make the seeding until the soil is well supplied with moisture to considerable depth.

According to the results of various trials made by the Station, alfalfa may well take the place of red clover, but attention must be paid to the possible need of both inoculation and liming. At the present time, due to the scarcity of American-grown red clover seed of a desirable kind, alfalfa is especially important.

WITH SPRING OATS

Clover and grass may be sown to advantage with spring oats. As with fall-sown oats, alfalfa may take the place of red clover in the spring seeding. In fact, there is considerable experimental and practical farm evidence showing that alfalfa is much more certain to come to a stand than red clover, provided, of course, that the soil is well supplied with lime. Under favorable conditions, as little as 10 pounds of alfalfa seed to the acre has been known to give a good stand. If desired, sweet clover may be used as a substitute for alfalfa. Also if the sufficiency of lime for alfalfa or sweet clover be doubted, Alsike clover may well take the place of red clover, at least until the red clover seed situation has been greatly improved.

VETCH WITH WINTER OATS

A seeding of hairy vetch and oats for hay may be made advantageously on a soil too poor in lime to produce either red or Alsike clover. The seeding should be done as early in September as possible. The resultant crop is found to vary greatly from year to year as to the proportions of vetch and oats; some years being more favorable to one and some to the other. It should be kept in mind that vetch is a very undesirable crop wherever wheat or other winter grain crop is to be grown, because it usually appears for some years after a seeding and the plants tangle and pull down the grain in spots; also the seed are harvested and threshed with the grain.

RAPE AND OATS

Rape may be sown with either winter or spring oats for pasture. In the former case, early fall seeding is desirable. In the latter, medium-early seeding is probably best. From 3 to 4 pounds of rape seed per acre is sufficient.



Experiments near Crossville, season of 1926

Upper picture—oats well fertilized

Lower picture—oats not fertilized

FERTILIZERS

Based on experiments conducted in various parts of the State, recommendations are given below in regard to the use of fertilizers.

Under certain conditions, fertilizers for the oat crop can be used to considerable advantage. The kind of fertilizer will depend largely

on the kind of soil, in particular its response to phosphate. For those portions of the State where commercial fertilizers are in common use, the following recommendations are made:

1. For oats alone—150 pounds of acid phosphate to the acre, to be applied at seeding time; and 50 pounds or more of nitrate of soda, usually to be top-dressed in early March for fall-sown oats, but if the seeding was late and there is need of increasing the fall growth to enable the plants to go safely through the winter, the nitrate may well be applied in the fall soon after the plants come up. A spring application of nitrate may be of much value in overcoming injury from aphids, which are appreciably less destructive on nitrated than on unnitrated oats, unless the soil be rich, in which case nitrate is inadvisable. In the case of spring-sown oats the nitrate should be applied as a top-dressing as soon as the plants are up.

2. For oats with alfalfa or clover and grass—when either alfalfa or a mixture of clover and grass is to be sown with the oats, the amount of phosphate may well be increased to 300 pounds per acre, on account of its value to the hay crops which follow the oats. Also, if the soil belong to the poorer class, which is somewhat in need of potash, 50 pounds of muriate of potash, or its equivalent of other potash salt, is advised, to be mixed with the acid phosphate. The addition of the potash salt is not expected to increase the oat yield but to be of value to the clover and grass crops. No change is advised in the nitrate application, especially as a too heavy growth of oats is unfavorable to the clover and grass.

Certain portions of the State, such as a large part of the Central Basin of Middle Tennessee and a considerable part of West Tennessee, are so well supplied with phosphate that the usual fertilizer mixtures have not proved profitable for farm crops. This may not mean that the soil is rich and well supplied with all the elements of plant food. In fact, such soils may be poor, owing to a need of nitrogen or some plant-food element other than phosphorus, which is the prominent constituent of the commercial mixtures. For a soil of this kind, nitrate of soda alone can be used as previously directed.

SUMMARY

1. The results of a 10-year trial at the Knoxville Station show that fall-sown, or winter, oats mature earlier and outyield spring oats. But spring oats fit into the average cropping system much better than winter oats.

2. Fulghum as a spring oat was found in a 5-year trial to be decidedly superior to Burt, which was formerly recognized as the best for Tennessee conditions.

3. Kanota, a Kansas strain of Fulghum, can be highly recommended for use in Tennessee.

4. Fulghum is not recommended for fall seeding anywhere in the State. Virginia Grey Turf is the most dependable winter oat on the market at the present time. Culberson, in long-continued trials at both the Knoxville and Jackson Stations, was found to yield equally with Grey Turf on good land, and to be 10 days earlier, and less apt to lodge.

5. Experiments carried out for 8 years to determine the comparative worth of home-grown, Texas-, and Arkansas-grown oat seed from the same original strain of Rust Proof gave no indication of superiority in any case, except as contamination with smut reduced the yields of the Arkansas-grown seed.

6. In a 9-year trial at the Knoxville Station, early March was found to be the most dependable time of seeding spring oats. February seedings were found not to be dependable, but may be advisable in the warmer parts of the State. On the Cumberland Plateau, and at similar elevations, seeding should be delayed until after the middle of March.

7. In 8 years of date-of-planting trials with winter oats at the Knoxville Station, September proved to be the best month. October seedings proved best in a 12-year trial at the Jackson Station, but seeding late in October should be avoided.

8. One bushel of seed per acre was found to be sufficient for fall-sown oats in a 9-year trial under favorable soil and climatic conditions at the Jackson Station. Under average or unfavorable conditions, a heavier seeding, $1\frac{1}{2}$ to 2 bushels per acre, is advised.

9. Alfalfa, clovers, and grass may be sown to advantage with either winter or spring oats, but a soil well supplied with lime is important. On limed land alfalfa is generally much superior to red clover.

10. For land too poor in lime for either alfalfa or clover, hairy vetch may be used with fall-sown oats, but it is liable to become a pest on a farm where wheat or other small grain is raised.

11. Rape may be advantageously sown for pasture with either winter or spring oats.

12. Fertilizers can be used profitably for the oat crop, but regard should be had to the soil needs. Directions are given for the use of fertilizers under various conditions.

THE UNIVERSITY OF TENNESSEE
AGRICULTURAL EXPERIMENT STATION
Knoxville

BULLETIN No. 137

MARCH, 1927

INFLUENCE OF COWPEA CROP ON
YIELD OF CORN

EXCHANGE
MAY 16 1927

1. Experiments in a Cowpea-Corn Rotation
2. Effects of Cowpeas and Soybeans Plant-
ed with Corn

By
C. A. MOOERS
Director and Agronomist



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INFLUENCE OF COWPEA CROP ON YIELD OF CORN

1. Experiments in a Cowpea-Corn Rotation
2. Effects of Cowpeas and Soybeans Planted with Corn

BY C. A. MOOERS
Director and Agronomist

INTRODUCTION

In a study of the influence of the cowpea crop on soil productivity, both winter and summer crops following require consideration. Wheat or other small grain can be planted in the fall to measure the effect of the summer's cowpea crop, as was done in the cowpea-wheat experiments described in Bulletin 135. The present publication has to do primarily with the effects of the cowpea crop on the corn crop of the following year. In addition, data are given showing the effects of planting either cowpeas or soybeans with the corn, as is not infrequently done in farm practice.

1. EXPERIMENTS IN A COWPEA-CORN ROTATION ON GRAVELLY DOLOMITE SOIL

Field experiments in which cowpeas were grown one year and corn the next were carried out continuously at the Knoxville Station for 20 years—1905-1924—10 crops of each kind being obtained. The soil used was a gravelly loam derived from the dolomite formation, and was a good representative of a prominent soil type of East Tennessee.

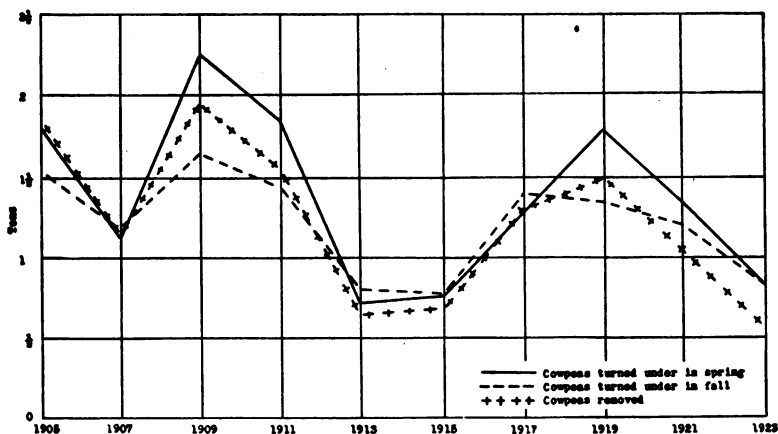


Chart 1—Yields of cowpea hay in cowpea-corn rotation—Knoxville

The soil was in a good state of productivity at the outset, but was not well enough supplied with plant food—nitrogen, in particular—to maintain high yields without manuring. Like applications of acid phosphate and muriate of potash were made under each of the experimental conditions, in order that the nitrogen supply might be the limiting factor so far as plant food was concerned.

Diagram 1 shows the divisions of the experimental range and the cropping system, which included continuous corn, corn after bare fallow, corn after cowpeas removed as hay, corn after cowpeas turned under in the fall, and corn after cowpeas left on the ground through the winter and turned under in the spring. This range was less than 100 feet from the cowpea-wheat experiments reported in Bulletin 135, but lay on a higher slope, where the soil was appreciably lighter in color, more gravelly, and less well supplied with nitrogen and humus.

TABLE 1—Yields per acre of cowpea hay and of corn for the 20-year period 1905-1924—fertilizer treatments the same under all conditions

| Plot
Crop
Disposition of cowpeas | Year | Cowpea hay | Corn | |
|--|------|------------|-------|--------|
| | | | Grain | Stover |
| | | Tons | Bu. | Tons |
| | 1906 | | 49.4 | 1.80 |
| | 1907 | | 58.9 | 2.00 |
| | 1908 | | 41.0 | 1.19 |
| | 1909 | | 52.7 | 1.78 |
| | 1910 | | 45.5 | 1.44 |
| | 1911 | | 45.2 | 1.60 |
| | 1912 | | 16.1 | 1.51 |
| 10, 11 | 1913 | | 24.6 | 1.02 |
| Continuous corn | 1914 | | 35.8 | 1.02 |
| No cowpeas | 1915 | | 27.9 | 1.39 |
| grown | 1916 | | 27.9 | 1.11 |
| | 1917 | | — | — |
| | 1918 | | 23.2 | 0.66 |
| | 1919 | | 17.3 | 0.89 |
| | 1920 | | 18.7 | 0.78 |
| | 1921 | | 23.6 | 0.41 |
| | 1922 | | 13.2 | 0.49 |
| | 1923 | | 14.6 | 0.49 |
| | 1924 | | 18.2 | 0.49 |
| Average 10 even years | | | 28.6 | 1.05 |
| Average 8 odd years | | | 33.1 | 1.20 |
| | 1906 | | 58.9 | 1.84 |
| | 1908 | | 43.7 | 1.20 |
| | 1910 | | 35.1 | 1.23 |
| 13 | 1912 | | 17.2 | 1.54 |
| Bare fallow in odd years, | 1914 | | 37.1 | 0.98 |
| corn in even years | 1916 | | 21.4 | 0.82 |
| No cowpeas | 1918 | | 15.7 | 0.58 |
| grown | 1920 | | 19.9 | 0.56 |
| | 1922 | | 8.6 | 0.40 |
| | 1924 | | 13.6 | 0.40 |
| Average 10 years | | | 27.1 | 0.96 |

TABLE 1—(Concluded)

| Plot
Crop
Disposition of cowpeas | Year | Cowpea hay | Corn | |
|--|------|------------|-------|--------|
| | | | Grain | Stover |
| | | Tons | Bu. | Tons |
| 14, 15
Cowpeas in odd years,
corn in even years
Cowpeas removed
as hay | 1905 | 1.86 | | |
| | 1906 | | 58.9 | 1.92 |
| | 1907 | 1.15 | | |
| | 1908 | | 40.9 | 1.32 |
| | 1909 | 1.94 | | |
| | 1910 | | 48.4 | 1.45 |
| | 1911 | 1.55 | | |
| | 1912 | | 20.7 | 1.73 |
| | 1913 | 0.65 | | |
| | 1914 | | 39.7 | 1.09 |
| | 1915 | 0.68 | | |
| | 1916 | | 36.5 | 1.19 |
| | 1917 | 1.31 | | |
| | 1918 | | 30.7 | 1.06 |
| | 1919 | 1.49 | | |
| | 1920 | | 26.7 | 1.01 |
| | 1921 | 1.03 | | |
| | 1922 | | 18.9 | 0.52 |
| | 1923 | 0.57 | | |
| | 1924 | | 28.8 | 0.66 |
| Average 10 years | | 1.22 | 84.0 | 1.20 |
| 16, 17
Cowpeas in odd years,
corn in even years
Cowpeas turned under
in spring | 1905 | 1.81 | | |
| | 1906 | | 58.7 | 1.95 |
| | 1907 | 1.12 | | |
| | 1908 | | 50.2 | 1.40 |
| | 1909 | 2.26 | | |
| | 1910 | | 57.1 | 1.71 |
| | 1911 | 1.87 | | |
| | 1912 | | 38.2 | 1.93 |
| | 1913 | 0.72 | | |
| | 1914 | | 44.7 | 1.25 |
| | 1915 | 0.76 | | |
| | 1916 | | 39.5 | 1.38 |
| | 1917 | 1.28 | | |
| | 1918 | | 34.3 | 1.28 |
| | 1919 | 1.79 | | |
| | 1920 | | 40.1 | 1.20 |
| | 1921 | 1.35 | | |
| | 1922 | | 27.2 | 0.72 |
| | 1923 | 0.83 | | |
| | 1924 | | 39.3 | 0.98 |
| Average 10 years | | 1.36 | 42.4 | 1.38 |
| 18, 19
Cowpeas in odd years,
corn in even years
Cowpeas turned under
in fall | 1905 | 1.54 | | |
| | 1906 | | 70.1 | 2.10 |
| | 1907 | 1.18 | | |
| | 1908 | | 43.3 | 1.32 |
| | 1909 | 1.66 | | |
| | 1910 | | 51.7 | 1.64 |
| | 1911 | 1.44 | | |
| | 1912 | | 35.0 | 1.91 |
| | 1913 | 0.81 | | |
| | 1914 | | 46.6 | 1.03 |
| | 1915 | 0.78 | | |
| | 1916 | | 41.7 | 1.49 |
| | 1917 | 1.40 | | |
| | 1918 | | 27.2 | 1.21 |
| | 1919 | 1.35 | | |
| | 1920 | | 32.8 | 1.30 |
| | 1921 | 1.21 | | |
| | 1922 | | 24.6 | 0.72 |
| | 1923 | 0.83 | | |
| | 1924 | | 32.2 | 0.73 |
| Average 10 years | | 1.27 | 40.5 | 1.35 |

| | |
|---|----|
| Continuous corn | 11 |
| Continuous corn | 12 |
| Corn after fallow | 13 |
| Corn after cowpeas removed | 14 |
| Corn after cowpeas removed | 15 |
| Corn after cowpeas turned under in spring | 16 |
| Corn after cowpeas turned under in spring | 17 |
| Corn after cowpeas turned under in fall | 18 |
| Corn after cowpeas turned under in fall | 19 |

Diagram 1—Experimental range in cowpea-corn rotation—each plot 1/40 acre—Knoxville Station

being 41.5 bushels per acre. The average for plots 14 and 15, where the cowpea crops were removed, was 34.0 bushels. The average for plots 10 and 11, where corn was grown continuously, was 28.6 bushels for the 10 even years, when corn was grown on all plots. Where a bare fallow was maintained, in the years when cowpeas were grown elsewhere, as indicated, the average yield of corn was 27.1 bushels per acre, or 1.5 bushels less than that for the same years under continuous corn.

Inspection of chart 2 shows that for the first 6 crops the yield of corn following cowpeas turned under in the fall was not materially different, on the average, from that obtained where the cowpea plants lay on top of the ground through the winter. On the other hand, the last 4 crops were in favor of the latter practice by an average of 6 bushels per acre. It is not unreasonable to assume

DISCUSSION OF THE DATA

Table 1 gives the yields of both cowpea hay and of corn under the various conditions. Chart 1 shows the yields of cowpea hay, and chart 2 the yields of corn, as obtained in the 20 years. The hay yields were only slightly greater where the crops were turned under than where removed—the averages being 1.22 tons per acre on plots 14 and 15, where the crops were removed; 1.36 tons on plots 16 and 17, where the crops were turned under in the spring; and 1.27 tons on plots 18 and 19, where the crops were turned under in the fall. In all cases there was a considerable amount of fallen leaves which could not be included in the yields.

The records show a similarity in the yields of cowpea hay under all the experimental conditions, with the tendency toward decreased yields; but it is evident that the nature of the season played a very important part, so that a more definite conclusion is hardly warranted.

The yields of corn as depicted in chart 2 show a decided falling off under all conditions throughout the period. As might be expected, the yields are best where the cowpea crops were turned under, the average for the 4 plots 16 to 19

that the fall plowing hastened the decomposition of the cowpea plants, and resulted in a greater loss of nitrogen by leaching than was the case under the other condition. The failure of the first 6 crops to show a definite difference may be attributed to the more fertile condition of the soil in the earlier years, when the limiting factor was moisture supply rather than nitrogen.

| Unlimed | Limed |
|----------------------------------|-------|
| Continuous corn
(Manured) | 6 |
| Continuous corn
(Manured) | 7 |
| (Not in the experiment) | 8 |
| Continuous corn | 9 |
| Corn after soybeans removed | 10 |
| Corn after soybeans turned under | 11 |
| Corn after cowpeas removed | 12 |
| Corn after cowpeas turned under | 13 |
| (Not in the experiment) | 14 |
| (Not in the experiment) | 15 |
| Continuous corn | 16 |

Diagram 2—Experimental range in summer legume-corn rotation—each plot 1/40 acre—Knox County

It is of interest to note that the yields of the first 5 corn crops from plots 14 and 15, where the cowpea hay was removed, were little different from those obtained in the same years from plots 10 and 11, where corn was grown continuously. For each of the last 5 years, however, the yields were decidedly in favor of plots 14 and 15; their average yield being greater by 8.1 bushels of corn per acre. Similarly, the evidence for the last 5 corn crops was favorable to continuous cropping in corn rather than to alternation with bare fallow, which was included for experimental purposes and not because of its possible practical value.

ON CHICKAMAUGA LIMESTONE SOIL

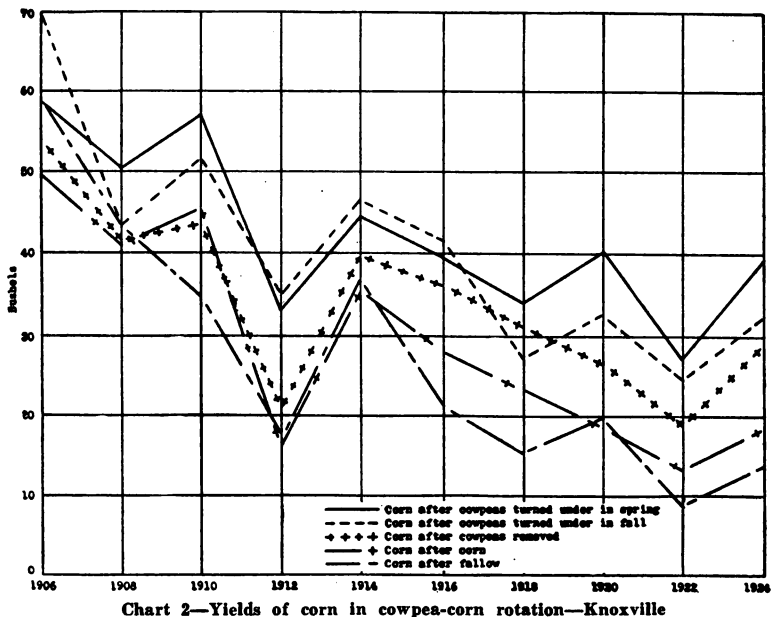
Similar experiments to those at the Knoxville Station were carried out for 12 years—1906-1917—on a rather heavy type of soil derived from the decomposition of the Chickamauga, or “rotten,” limestone. This soil was grayish when dry, but of a light brown color when wet. The subsoil was heavy and of a yellowish-red color. Both the soil and subsoil were appreciably heavier and less granular than those at the Experiment Station.

These experiments differ from those at Knoxville in two important particulars; first that data are available for both limed and unlimed conditions, and, secondly, that comparative data were obtained from light applications of farmyard manure.

TABLE 2—Yields per acre of legume (cowpea and soybean) hay and of corn under various experimental conditions—experiments conducted in Knox County on heavy silt loam derived from Chickamauga limestone

| Plot
Crop
Disposition
of legume | Manure
and
ferti-
liser | Legume hay | | | | Corn | | | | | | |
|---|--|------------|-------|--------------|--------------|------|-------|--------|---------|--------|---------|--------|
| | | Year | Limed | Un-
limed | Aver-
age | Year | Limed | | Unlimed | | Average | |
| | | | | | | | Grain | Stover | Grain | Stover | Grain | Stover |
| 6, 7
Continuous
corn
No
legume | 6 tons
manure
per acre
every 2
years,
begin-
ning 1906
—80 tons
in all | | Tons | Tons | Tons | 1907 | — | — | — | — | 14.8 | 0.84 |
| | | | | | | 1909 | 64.9 | 2.08 | 55.0 | 1.90 | 60.0 | 1.99 |
| | | | | | | 1911 | 45.7 | — | 35.0 | — | 40.4 | — |
| | | | | | | 1913 | 31.4 | — | 27.5 | — | 29.5 | — |
| | | | | | | 1914 | 43.0 | 1.16 | 39.7 | 0.89 | 41.4 | 1.03 |
| | | | | | | 1916 | 48.8 | — | 35.1 | — | 41.7 | — |
| | Average | | | | | | 46.7 | 1.62 | 38.5 | 1.40 | 38.0 | 1.29 |
| 9, 16
Continuous
corn
No
legume | 200 lbs.
phos-
phate,
25 lbs.
potash
per acre
every 2
years,
begin-
ning 1906 | | | | | 1907 | — | — | — | — | 22.9 | 1.04 |
| | | | | | | 1909 | 51.4 | 1.44 | 45.0 | 1.32 | 48.2 | 1.38 |
| | | | | | | 1911 | 31.4 | — | 26.9 | — | 29.2 | — |
| | | | | | | 1913 | 15.4 | — | 12.7 | — | 14.1 | — |
| | | | | | | 1914 | 32.5 | 0.70 | 26.4 | 0.57 | 29.5 | 0.64 |
| | | | | | | 1916 | 24.2 | — | 13.3 | — | 18.8 | — |
| | Average | | | | | | 31.0 | 1.07 | 24.9 | 0.95 | 27.1 | 1.02 |
| 10, 12
Soybeans
on plot 10,
cowpeas on
plot 12
Removed as
hay | Phos-
phate
and pot-
ash as
for plots
9 and 16 | 1906 | — | — | 1.59 | 1907 | — | — | — | — | 23.7 | 1.40 |
| | | 1908 | — | — | 1.42 | 1909 | 57.9 | 1.50 | 53.6 | 1.51 | 55.8 | 1.51 |
| | | 1910 | 1.11 | 0.60 | 0.86 | 1911 | 48.4 | — | 36.8 | — | 42.6 | — |
| | | 1912 | 1.37 | 0.75 | 1.06 | 1913 | 25.3 | — | 20.7 | — | 23.0 | — |
| | | 1915 | 1.24 | 0.90 | 1.07 | 1914 | 38.2 | 0.88 | 33.8 | 0.73 | 36.0 | 0.81 |
| | | 1917 | 1.22 | 0.89 | 1.06 | 1916 | 38.6 | — | 25.0 | — | 31.8 | — |
| | Average | 1.24 | 0.79 | 1.18 | — | 41.7 | 1.19 | 34.0 | 1.12 | 35.5 | 1.24 | |
| 11, 13
Soybeans
on plot
11, cowpeas
on plot 13
Turned under | Phos-
phate
and pot-
ash as
for plots
9 and 16 | 1906 | — | — | 1.59 | 1907 | — | — | — | — | 25.7 | 1.22 |
| | | 1908 | — | — | 1.53 | 1909 | 64.5 | 2.08 | 53.6 | 1.92 | 59.1 | 2.00 |
| | | 1910 | 1.08 | 0.61 | 0.85 | 1911 | 57.1 | — | 41.8 | — | 49.5 | — |
| | | 1912 | 1.43 | 0.71 | 1.07 | 1913 | 26.9 | — | 21.4 | — | 24.2 | — |
| | | 1915 | 1.28 | 0.93 | 1.11 | 1914 | 43.9 | 1.11 | 36.1 | 0.82 | 40.0 | 0.97 |
| | | 1917 | 1.30 | 0.84 | 1.07 | 1916 | 47.2 | — | 31.5 | — | 39.4 | — |
| | Average | 1.27 | 0.77 | 1.21 | — | 47.9 | 1.60 | 36.9 | 1.37 | 39.7 | 1.40 | |

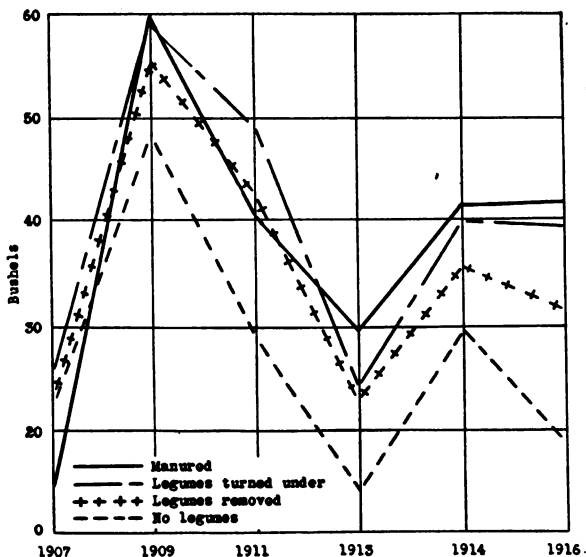
Another difference in these experiments is that cowpeas were used in one set and soybeans in another. With regard to these summer legumes no material conclusion seems warranted other than that their behavior was much the same under the various conditions and their effects on corn were similar. The results were therefore averaged, and the data so obtained are given in table 2.



DISCUSSION OF THE DATA

EFFECTS OF THE LEGUMES ON THE CORN CROPS

Chart 3 presents graphically the yields of the 6 corn crops as influenced by the various conditions. It is evident, above all other considerations, that the legumes, whether removed or turned under, materially increased the yields of corn. Where they were removed the yields were intermediate between those obtained where no legume was grown and where the legumes were turned under. The



average yields of corn per acre for the 6 crops were as follows: No legumes, 27.1 bushels; legumes removed, 35.5 bushels; legumes turned under, 39.7 bushels. Although these differences in yield were fairly consistent throughout the period, a tendency is seen in the last 2 crops toward wider differences—the yields of corn holding up best where the legumes were turned under.

The superior yields of corn are noticeable where the legumes were removed, as compared with those where no legumes were grown. At Knoxville the yields of corn under these two conditions were very nearly the same for the first 5 crops; only in the last 5 was the favorable effect of the cowpeas plainly apparent. This difference in the outcome of the two series can be reasonably attributed, in large part, to differences in soil texture and structure. At Knoxville the soil was a well-granulated loam, whose physical condition was little improved, if at all, by the cowpea crops. The other soil was noticeably improved in structure by the legume crops, which made it more friable and granular—a condition that was evident to the plowman.

At best, the after-effects of summer legumes such as these are rated as small in comparison with those of crops like red clover and alfalfa.

MANURE VALUE

Two plots, Nos. 6 and 7, were manured at the rate of 6 tons per acre once in 2 years, or 30 tons for the 12 years, and corn grown continuously. The yields, as obtained in the corn years for the other plots, are given in table 2. Chart 3 shows that the yields were similar to those where the legumes were turned under, the latter having a slightly better average by 1.7 bushels per acre.

A more definite idea of the money value of the manure may be gained by comparing the yields obtained from the manured plots 6 and 7 with those from the unmanured plots 9 and 16, both sets having produced 11 crops of corn continuously from 1906 to 1916. The average yield for this period was 38.1 bushels per acre for the manured plots and 25.1 bushels for the unmanured plots. The gain from 30 tons of manure is therefore 143 bushels. The price of corn is variable, but if it is placed at \$1.00 per bushel, each ton of manure added \$4.77 to the gross value of the corn crop. If the cost of the fertilizers used on plots 9 and 16 be taken into consideration, the value of the manure will be still further enhanced, because the mineral fertilizers increased the corn crops under the condition of continuous corn without manure, but proved of no value when applied with the manure.

EFFECTS OF LIMING

In March 1909, the fourth year of these experiments, ground limestone was applied at the rate of 2 tons per acre to one half of every plot. The yields of the 9 crops grown thereafter were obtained under both the limed and unlimed conditions, and the data are given in table 2. The effect of liming on the yield of legume hay is shown by chart 4, and on the yield of corn by charts 5 and 6.

All crops were greatly increased by liming. The legume hay produced without lime on plots 10 to 13 averaged only 0.78 ton per acre for the 4 crops grown. With lime, the average was 1.26 tons,

an increase of nearly 62 per cent. The limed sections of the manured plots 6 and 7 gave an average yield of 46.7 bushels of corn per acre for the 5 crops of the corn years in rotation, as compared with 38.5 bushels from the unlimed sections. On plots 9 and 16, where corn was grown continuously without manure or legumes, the average yields per acre in the corn years were 31.0 bushels for the limed sections and 24.9 bushels for the unlimed. On plots 10 to 13, where the legumes were grown in alternate years, the average yield of corn on the limed sections was 44.8 bushels, and on the unlimed 35.5 bushels. The effect of liming was therefore almost equally marked under all of the experimental conditions, with an annual average increase of nearly 8 bushels per acre.

Inspection of the charts shows that during the 8-year period covered by the record there was little decrease in the effectiveness of the liming.

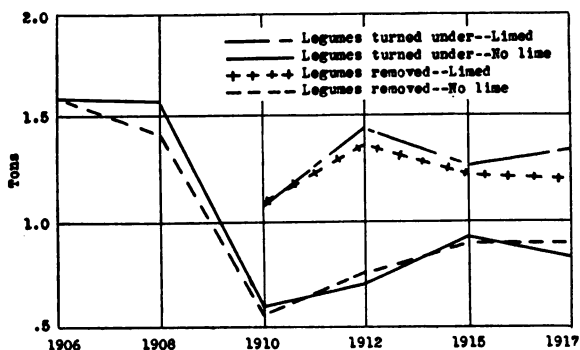


Chart 4—Yields of legume hay with and without liming—Knox County

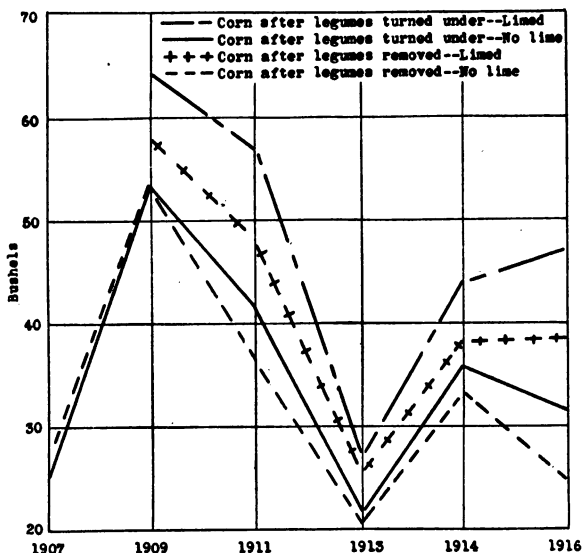


Chart 5—Yields of corn with and without liming—Knox County

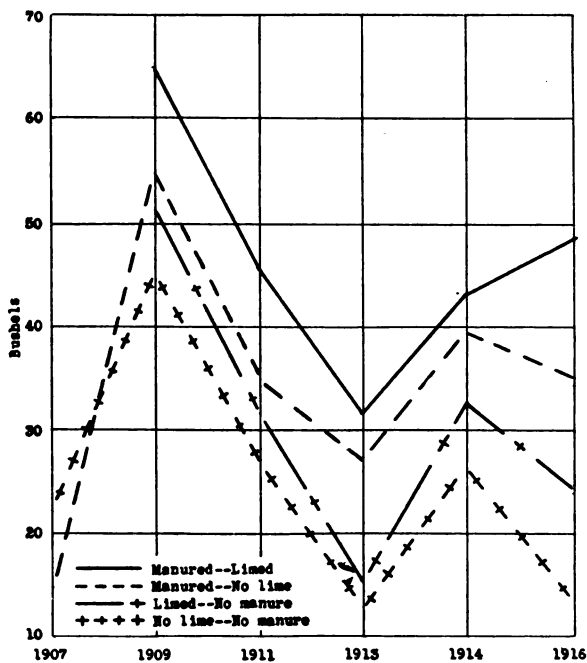


Chart 6—Yields of corn on manured and unmanured plots as affected by liming—Knox County

2. EFFECTS OF COWPEAS AND SOYBEANS PLANTED WITH CORN

PLANTED IN ROW WITH CORN

A common practice in some parts of the State is to plant either soybeans or cowpeas in the same row with corn. Soybeans are now generally preferred for this purpose because they are better adapted to early planting and are more productive than cowpeas. The question is often asked as to how much the yield of corn is reduced in a planting of this kind. Table 3 gives the data from 6 years' trials at the Knoxville Station and 4 years' at the Jackson Station. At each place the yields of corn were obtained when the crop was grown both alone and with either cowpeas or soybeans. Tokio, a late-maturing variety, fully as vigorous as Mammoth Yellow, was used in all the trials with soybeans. The rate of planting was about one bushel to 8 acres. In the trials with cowpeas the Whippoorwill variety was used, but the rate of planting was somewhat higher than for the soybeans. In all cases the corn was planted at a suitable rate for grain production.

TABLE 3—Yields obtained from corn and Tokio soybeans, each planted alone, and from mixtures of (1) corn and Tokio soybeans and (2) corn and Whippoorwill cowpeas

| Locality | Year | Variety | Yields per acre | | | |
|------------------------------|------|--------------|-----------------|----------------------------|---------------|-------------|
| | | | Corn alone | Corn with beans or cowpeas | | Beans alone |
| | | | | Corn | Beans or peas | |
| | | Soybeans | Bu. | Bu. | Bu. | Bu. |
| Knoxville | 1915 | Tokio | 32.6 | 21.4 | 11.8 | 18.3 |
| Knoxville | 1916 | Tokio | 45.5 | 39.3 | 17.6 | 29.7 |
| Jackson | 1917 | Tokio | 68.0 | 49.8 | 6.7 | 17.6 |
| Jackson | 1919 | Tokio | 62.8 | 30.7 | 25.0 | 35.4 |
| Jackson | 1921 | Tokio | 51.8 | 29.3 | 31.5 | 36.1 |
| Jackson | 1922 | Tokio | 38.8 | 23.0 | 10.2 | 18.4 |
| | | Cowpeas | | | | |
| Knoxville | 1906 | Whippoorwill | 45.5 | 36.8 | 10.0 | — |
| Knoxville | 1907 | Whippoorwill | 49.1 | 30.5 | 8.4 | — |
| Knoxville | 1909 | Whippoorwill | 35.1 | 19.8 | 11.0 | — |
| Knoxville | 1915 | Whippoorwill | 27.7 | 21.4 | 3.8 | — |
| Averages: | | | | | | |
| Tokio soybeans—6 crops | | | 49.9 | 32.3 | 17.1 | 25.9 |
| Whippoorwill cowpeas—4 crops | | | 39.4 | 27.1 | 8.2 | — |

DISCUSSION OF THE DATA

With soils of good productivity, such as were used in the experiments, the moisture supply is frequently the limiting factor in crop production; hence, it is not surprising to find that both the soybeans and the cowpeas materially reduced the yields of the corn with which they were planted. The average yield of the 6 crops of corn grown with soybeans was 32.3 bushels per acre, whereas, under otherwise like conditions corn alone produced 49.9 bushels, or 17.6 bushels more to the acre. As an offset, the yield of beans planted with the corn was 17.1 bushels per acre. The average yield of the 4 crops of corn where planted with cowpeas was 27.1 bushels per acre, as compared with the average of 39.4 bushels for corn alone—a difference of 12.3 bushels to the acre. The average yield of cowpeas planted with corn was only 8.2 bushels per acre.

It is noticeable that the reduction in yield of corn due to the legume varies greatly from year to year. At Knoxville in 1916 the soybeans reduced the yield of corn only 6.2 bushels per acre. On the other hand, at Jackson, in 1919, the soybeans reduced the yield of corn 32.1 bushels. As a rule, however, the yield of soybeans nearly offsets, bushel for bushel, the decrease in corn. As a balanced ration for hogs or for soil-improvement the mixture of corn and beans would evidently be advantageous.

The question may be asked as to the value of a mixed crop of corn and soybeans as compared with a crop from the same area, one half planted to corn alone and the other half to soybeans alone. The data of table 3 show that as an average for the 6 years of trial the mixed crop produced a total of 49.4 bushels per acre of corn and soybeans, as compared with 37.9 bushels per acre where the same crops were planted separately. The evidence is therefore highly favorable to the mixture, if only grain and seed production are considered.

COWPEAS SOWN BROADCAST AT LAST CULTIVATION OF CORN

The last question for consideration is the effect of cowpeas when sown broadcast at the last cultivation of corn—a not uncommon practice in various parts of the State. To answer this question, data have been obtained for 17 years from 4 plots of range 1 at the Jackson Station. Plots 14 and 15 were planted continuously to corn without cowpeas. Plots 16 and 17 were planted continuously to corn, and Whippoorwill cowpeas were sown broadcast at the rate of 1/2 bushel per acre at the last cultivation of the corn. The average date of planting of the corn was April 26. The cowpeas were generally sown the latter part of June. One plot of each set (Nos. 14 and 16) was manured every year at the rate of 5 tons per acre. Plots 15 and 17 were unmanured. All the crops, both grain and stover, were removed annually. The yields of corn under the various conditions are given in table 4 and are shown graphically in chart 7.

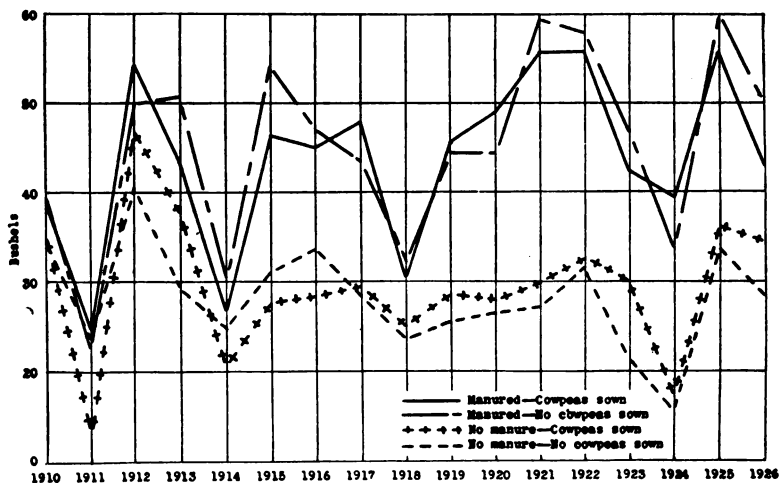


Chart 7.—Yields of corn grown with and without cowpeas sown broadcast at the last cultivation—continuous experiments for 17 years under manured and unmanured conditions at the Jackson Station

TABLE 4—*Effect on the yield of corn produced by cowpeas sown broadcast at the last cultivation of the corn—continuous experiments for 17 years under both manured and unmanured conditions at the Jackson Station*

| Year | Manure per acre | Plot | Yields of corn—
no cowpeas grown | | Plot | Yields of corn—
cowpeas sown at last cultivation | | Remarks |
|----------------|-----------------|--------------|-------------------------------------|--------|------|---|--------|---------------------------------------|
| | | | Grain | Stover | | Grain | Stover | |
| | | | Bu. | Tons | | Bu. | Tons | |
| 1910 | 5 tons | 14 | 38.4 | 1.60 | 16 | 39.4 | 1.68 | Light crop of cowpeas |
| | None | 15 | 34.4 | 1.44 | 17 | 34.9 | 1.40 | |
| 1911 | 5 tons | 14 | 25.0 | 1.08 | 16 | 22.9 | 1.10 | Good crop of cowpeas |
| | None | 15 | 23.9 | 0.90 | 17 | 13.2 | 0.78 | |
| 1912 | 5 tons | 14 | 54.3 | 1.86 | 16 | 50.0 | 1.76 | |
| | None | 15 | 40.7 | 1.54 | 17 | 47.1 | 1.84 | |
| 1913 | 5 tons | 14 | 43.2 | 1.30 | 16 | 50.7 | 1.34 | |
| | None | 15 | 29.2 | 0.92 | 17 | 37.8 | 1.00 | |
| 1914 | 5 tons | 14 | 26.8 | 1.72 | 16 | 30.0 | 1.30 | Cowpeas made little growth |
| | None | 15 | 25.0 | 1.24 | 17 | 20.7 | 1.20 | |
| 1915 | 5 tons | 14 | 46.4 | 1.42 | 16 | 53.9 | 1.54 | Cowpeas made little growth |
| | None | 15 | 31.0 | 0.80 | 17 | 27.8 | 0.74 | |
| 1916 | 5 tons | 14 | 45.0 | 2.24 | 16 | 47.0 | 2.08 | |
| | None | 15 | 33.5 | 1.32 | 17 | 28.5 | 1.56 | |
| 1917 | 5 tons | 14 | 47.9 | 2.20 | 16 | 43.6 | 1.82 | |
| | None | 15 | 23.2 | 1.24 | 17 | 29.3 | 1.38 | |
| 1918 | 5 tons | 14 | 30.4 | 1.26 | 16 | 32.1 | 1.22 | No stand of cowpeas obtained |
| | None | 15 | 23.6 | 0.62 | 17 | 25.0 | 0.62 | |
| 1919 | 5 tons | 14 | 45.7 | 1.62 | 16 | 44.3 | 1.71 | No cowpeas sown—corn badly blown down |
| | None | 15 | 25.4 | 0.78 | 17 | 23.2 | 0.82 | |
| 1920 | 5 tons | 14 | 48.9 | 1.40 | 16 | 44.3 | 1.34 | Cowpeas made very little growth |
| | None | 15 | 26.4 | 0.76 | 17 | 27.9 | 0.76 | |
| 1921 | 5 tons | 14 | 55.7 | 2.06 | 16 | 59.3 | 1.98 | |
| | None | 15 | 27.1 | 0.93 | 17 | 30.0 | 0.93 | |
| 1922 | 5 tons | 14 | 55.7 | 1.58 | 16 | 57.9 | 1.53 | |
| | None | 15 | 31.4 | 0.96 | 17 | 32.5 | 0.96 | |
| 1923 | 5 tons | 14 | 42.2 | 1.58 | 16 | 46.4 | 1.61 | |
| | None | 15 | 21.4 | 0.79 | 17 | 30.0 | 0.92 | |
| 1924 | 5 tons | 14 | 39.3 | 1.92 | 16 | 33.7 | 1.94 | Cowpeas a failure |
| | None | 15 | 15.7 | 1.11 | 17 | 17.1 | 1.26 | |
| 1925 | 5 tons | 14 | 55.7 | 1.44 | 16 | 60.0 | 1.74 | Cowpeas made little growth |
| | None | 15 | 33.6 | 0.76 | 17 | 36.1 | 0.96 | |
| 1926 | 5 tons | 14 | 42.9 | 2.66 | 16 | 50.0 | 2.38 | |
| | None | 15 | 28.6 | 1.12 | 17 | 34.3 | 1.22 | |
| Averages: | | | | | | | | |
| Manured | { | 17 yrs. | 43.7 | 1.70 | | 45.0 | 1.68 | |
| | | Last 12 yrs. | 46.3 | 1.78 | | 47.7 | 1.74 | |
| Unma-
nured | { | 17 yrs. | 28.2 | 1.01 | | 29.4 | 1.08 | |
| | | Last 12 yrs. | 27.2 | 0.93 | | 28.9 | 1.01 | |

DISCUSSION OF THE DATA

EFFECTS OF COWPEA CROPS ON YIELD OF CORN

The data are of special interest, both because of the suitability of the soil and manurial conditions to the objects in view, and because of the duration of the experiments. As is well known in farm practice, the cowpea crop from a seeding in corn at the last cultivation is uncertain; that is, there are frequent failures. The record in this case shows that in 8 of the 17 years the cowpeas either failed completely or made only a light growth. For 9 years, on the other hand, the growth may be described as good for a seeding of this kind. Occasionally an extra-good crop was obtained.

The average acre yields of corn for the 17 years on the manured plots were 43.7 bushels of grain and 1.70 tons of stover where cowpeas were not grown, and 45.0 bushels of grain and 1.68 tons of stover where cowpeas were grown. Without manuring the average yields were 29.2 bushels of corn and 1.01 tons of stover for the no-cowpea plots, and 29.4 bushels of corn and 1.08 tons of stover for the cowpea plots.

Chart 7 gives no certain evidence of changing relationships in the case of the manured plots, and the differences between the yields on the two unmanured plots have remained nearly constant for the last 10 years. Attention may be called to the fact that even adjacent plots are seldom of exactly the same productivity. The effect on the yield of corn is therefore little in evidence, whether from the viewpoint of average yields or of tendency for the period. Such a tendency as may be construed to exist is favorable to the practice so far as the yield of corn is concerned.

MANURE VALUE

For the first 5 years yard manure of inferior value was used. Beginning with 1915, or for the last 12 years, good-quality farm-yard manure was applied regularly, and the data for this period are considered to give a fair index of its value. Manure, however, not only is of variable quality, depending on the kind of livestock, the feeding, and other factors, but the response is not the same under different soil conditions, some soils being decidedly more responsive than others. In this set of experiments the average annual increase in yield of corn attributable to manuring for the last 12 years was 18.9 bushels per acre, or 3.8 bushels for each ton of manure used.

SUMMARY

EXPERIMENTS IN A COWPEA-CORN ROTATION

1. Experiments in a 2-year rotation of corn and cowpeas were carried out continuously for 20 years at the Knoxville Station. The main object was to determine the influence of the cowpea crop on the yield of corn.

2. The yields of cowpea hay were well maintained throughout the period under all the experimental conditions. The average for all plots was 1.28 tons per acre—a good average for the State.

3. The yields of corn showed a decidedly downward trend under all the experimental conditions, including the turning under of all cowpea crops.

4. The lowest average yield of corn, 27.1 bushels per acre, was obtained where the corn followed a bare fallow of the previous year. The average yield for the same years where corn was grown continuously was little better, being only 28.6 bushels.

5. The average yield of corn following the continued removal of the cowpea crops as hay was 34.0 bushels per acre, or 5.4 bushels more than the average for the same years where corn was grown continuously.

6. The highest average yield, 42.4 bushels per acre, was obtained where the cowpea crops were allowed to mature and were left every year on the surface of the ground throughout the winter.

7. The next highest yield, 40.8 bushels per acre, was obtained where the cowpea crops were turned under every fall.

8. The difference in favor of the turning under of the cowpea crop in the spring was not noticeable until after the sixth corn crop, but averaged 6 bushels per acre for the 4 crops thereafter.

9. A similar series of experiments was carried out for 12 years on a poorer type of soil located about six miles south of Knoxville. In this series data were obtained for 8 years under both limed and unlimed conditions. Also experiments with farmyard manure were included.

10. Both cowpeas and soybeans were grown in alternation with corn. The average yield of hay for all plots and conditions was 1.20 tons per acre for the 6 crops grown.

11. The last 4 crops of legumes were grown both with and without lime. Without lime the average was 0.78 ton per acre; with lime the average was 1.27 tons, an increase of 0.49 ton, or nearly 63 per cent.

12. Where corn was grown continuously the average yield was 27.1 bushels per acre.

13. With the legumes removed as hay, the average yield of corn following was 35.5 bushels per acre—a gain of 8.4 bushels over the yield for continuous corn for the same years. This marked increase is attributed in part to the evident loosening and granulating effect of the cowpea and soybean crops on this soil, which was of a somewhat heavy, close type.

14. Where the legumes were turned under the average yield of corn per acre was 39.7 bushels, which was only 4.2 bushels larger than where the hay crops were removed.

15. Manure was applied to 2 plots at the rate of 6 tons per acre every other year. The average yield was 38.0 bushels per acre, lacking only 1.7 bushels of being equal to that obtained where the legume crops were turned under.

16. With the 11 crops of corn taken into consideration, the average increase in yield per ton of manure was 4.77 bushels.

17. Liming greatly increased the corn crops every year under all conditions. Under manuring the average increase from liming was 8.2 bushels per acre; without manure, and corn grown continuously, the average increase was 6.1 bushels; and where legumes were grown the average increase was 9.3 bushels.

18. No diminution in the effectiveness of the liming was evident, although only a single application of 2 tons of ground limestone per acre was made.

19. General conclusions: It is unprofitable to turn under a cowpea or soybean crop for the sake of increasing the productivity of the soil as measured by the corn crop of the following year. It is evident, however, that a much better than average condition can be expected where the legumes are pastured off or are fed as hay and the manure returned. Even when the summer legume is removed as hay a larger corn crop may be expected than where corn follows corn, but the effect is small in comparison with the after-effects of such legumes as red clover and alfalfa.

EFFECTS OF COWPEAS AND SOYBEANS PLANTED WITH CORN

1. Experiments were carried out for 6 years with soybeans and for 4 years with cowpeas to determine the effects of these crops when planted in the row with the corn, a not uncommon practice. In every case the yields of corn were greatly reduced, the average reduction for the 10 years' trial being 15.5 bushels per acre.

2. The average yield of soybeans when planted with corn was 17.1 bushels per acre, but that of cowpeas was only 8.2 bushels.

3. The average yield of 6 crops of soybeans planted alone was 25.9 bushels per acre. The reduction in yield when the soybeans were planted with corn was 8.8 bushels, or 34 per cent.

4. The mixed crop of corn and Tokio soybeans produced, as a 6-year average, 49.9 bushels of grain and seed per acre, as compared with an average of only 37.9 bushels per acre when the 2 crops were planted separately on equal areas.

5. The practice of planting soybeans with the corn is considered advantageous from the point of view of soil productivity and the increased value of the crop for "hogging-off" purposes.

6. In 8 out of 17 years of trial at the Jackson Station cowpeas sown broadcast in corn at the last cultivation either failed completely or made only a light and unprofitable crop. This was true both with and without an annual application of 5 tons per acre of farmyard manure.

7. There was no indication under either the manured or unmanured condition that the yields of corn were reduced by a seeding of this kind.

8. With the results of the last 12 years at the Jackson Station taken as the more reliable guide, each ton of manure produced, on the average, an increase of 3.8 bushels of corn and 1420 pounds of stover per acre.

